VETERINARY HYGIENE

CARE OF HEALTH

and

General Science of Contagious Diseases

of

Domesticated Animals

By

Dr. phil. et med. vet. Martin Klimmer,

Chief Health Officer,

Professor of Veterinary Hygiene and Director of the Hygienic Institute and the Experiment Station of the Veterinary High School, Dresden.

Third, Newly Revised Edition

With 270 Illustrations.

Authorized Translation

by

A. A. Leibold, D. V. M.

Formerly Professor of Physiology and Hygiene, later Professor of Pathology and Bacteriology at The Chicago Veterinary College; Translator of "Epizoötics and Their Control During War"; etc., etc.

Chicago, U. S. A.
ALEXANDER EGER,
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TRANSLATOR'S PREFACE

Klimmer's *"Veterinaerhygiene,"* having met with such widespread favor as an authoritative and comprehensive treatise on the subject of hygiene, feeding, care of animals and all that is generally included under these headings, it was concluded by certain American veterinarians and the publisher who were familiar with the volumes, that it should be translated into English and so give all English reading individuals the benefit of Professor Klimmer's extensive experience and sound teachings.

The work is not only applicable to the class room of the veterinary student and practitioner but likewise to those pursuing agriculture and animal husbandry.

In translating the original German text it was always my object to give the ideas in as literal a manner as possible, but still not translate word for word. Very frequently it became necessary to translate in a certain figurative manner. All of the original cuts, graphs and figures have been included and the explanatory notes translated.

It was considered important to add occasional notations regarding conditions and occurrences in countries other than considered by Dr. Klimmer. Such notes have the contributor's initials following them.

The translation of the fourth section of this volume is hereby credited to Dr. Paul Fischer, who likewise translated the entire volume entitled "The Scientific Feeding of Animals." Special credit is due him as this section is particularly tedious and he performed it in a most painstaking and conscientious manner.

I wish to express my particular indebtedness and appreciation for the helpful assistance that Dr. John R. Mohler, Chief, Bureau of Animal Industry, U. S. Department of Agriculture, gave in the preparation of this translation. He kindly reviewed the entire manuscript and made valuable suggestions and annotations with the object of making the book answer more in detail the needs of the English speaking veterinary world. His high government position and exceptional professional standing admirably qualify him to do this, as he has access to a great mass of literature and comes in intimate contact with the veterinary hygienic conditions of the world. Annotations made by Dr. Mohler are indicated by his initials—J. R. M.

I, at this time, also want to express my appreciation for helpful suggestions and advice kindly given me by a number of other friends during the preparation of this work.

Appreciation is also due to the publisher, Mr. Alexander Eger, who has offered every facility, whenever opportunity presented itself, in order that this work may be as nearly perfect as possible.

A. A. LEIBOLD.

January, 1923.

TRANSLATOR'S NOTICE

The first two editions of Klimmer's Veterinary Hygiene were published as single volumes and embodied a section on Feeds and Feeding of animals. However, owing to the fact that this third edition is much more comprehensive than the previous ones and since the science of feeds and feeding is taught in all veterinary institutions as a separate subject, the author decided to omit the section on feeds and feeding from this volume and issue it as a separate book under the title of "The Scientific Feeding of Animals."

EXCERPT FROM THE AUTHOR'S PREFACE OF THE FIRST EDITION

The well-known fact that it is a better policy to prevent diseases rather than to cure them, makes the great significance of the care of health as a practical and exceptionally important science plainly evident. Taking care of health is knowledge that is indispensable not only to the veterinarian but also to every livestock owner. Due to modern methods of management and the excessive use to which agricultural animals are put, it is often unavoidable, in order to obtain as great a return from the animals as possible, that they are brought under living conditions which deviate more or less from the normal. In order to meet all dangers to the life and health of animals that might arise therefrom, it is necessary to make use of all known means which science and experience have given to prevent such dangers. This book should give the opportunity to inform one's self on pertinent questions easily and quickly. Therefore the practical side of the individual questions has been considered in relation with the theoretical side.

In selecting the methods of examination I have in each case endeavored to emphasize as much as possible procedures that could be carried out the easiest under the most exacting conditions.

Dresden—Autumn, 1907.

EXCERPT FROM THE PREFACE OF THE AUTHOR'S SECOND EDITION

Practically all sections have been revised more or less. The chapters "Examination of Feeds" and "Infectious and Invasion Diseases" have been newly added. By the introduction of 126 new illustrations I believe I have very materially improved the appearance.

In the introduction to "Examination of Feeds" I had perforce to omit going into great detail in the microscopic methods as well as others. For more exhaustive methods see "Manual of Examination of Feeds", Beythien, Hartwich and Klimmer, published by Chr. Herm. Tauchnitz, Leipzig.

I have given as much consideration to the practical requirements under "Significance of Hygiene" as possible.

In the section "Infectious and Invasion Diseases" I have also omitted in this edition the etiology, specific diagnosis, prophylaxis and therapy. The latter part was edited with the collaboration of many authors by Klimmer and Wolff-Eisner as a separate work "Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine" and published by Dr. W.

Klinkhardt, Leipzig. The etiology should also be edited as a separate work; this has been begun. In order to avoid repetition of the works just named I have confined myself in the section "Infectious and Invasion Diseases" to general discussions and the laws on disinfection.

A year ago a Russian translation of "Veterinary Hygiene" appeared.

Dresden, November, 1913.

EXCERPT FROM PREFACE OF THE AUTHOR'S THIRD EDITION

In the new veterinary study-plan and the new order of examination for veterinarians the Care of Health of Domesticated Animals is separated from the Science of Feeding. This has induced me to edit my book "Veterinary Hygiene" as two independent works, viz: "The Care of Health" and "The Scientific Feeding of Animals."

In the revision of "The Care of Health" numerous, and in part quite comprehensive supplements, had to be taken up in all parts. Among the larger, newly added sections the one which deals with "General Considerations of Infectious Diseases" is to be mentioned first, which appeared in the "Infectious and Invasion Diseases" section of the second edition. In order to comply with the often expressed wish I have added detailed discussions on Immunity, Disinfection, Removal of Carcasses and their Utilization. Furthermore, in the section "Pastures" I have thoroughly considered from a practical standpoint the unfortunately very important pasture diseases as well as the measures for their prevention. In the section "Stable" the housing facilities for dogs and fowls have been considered in detail for the first time. Among the smaller supplements the revised communication on photodynamic substances (in section on Atmosphere, Light) are to be mentioned; also the poisonous Cryptogams (injuries to feeds, poisonous plants); skin parasites; care of the legs; vices and their removal; harness, as well as birth and obstetrical help (management and use of animals); the historical sketch on the development of hygiene, etc. By introducing 99 new illustrations I believe I have materially improved the clarity of the discussions.

In the revision I have also taken pains to lay as much emphasis as possible upon the veterinary and agricultural requirements in the exceptionally great practical importance of the care of the health.

I sincerely thank Dr. Haupt and Dr. Schadowski for the painstaking work of reading the proofs. I likewise owe thanks to the publisher, Paul Parey, for always being ready to grant me my wishes.

May the newly revised third edition of "The Care of Health" and "General Science of Contagious Diseases" meet with the same warm reception and review, as its predecessors.

M. KLIMMER.

Dresden, Autumn, 1920.

CONTENTS

SECTION IV

Noxious Agents in Feeds

SECTION V

The Care and Management of Animals

SECTION VI

The Pasture and Exercising Lot

SECTION VII

The Stable

SECTION VIII

Contagious Diseases

Introduction

The sanitary care of domestic animals, or veterinary hygiene, is that part of veterinary science which enables us to recognize the causes of disease and teaches us to prevent diseases through defense against the causes and through increasing the resistance of the animal in so far as this is possible without encroaching upon rational economy. Hygiene is preventive medicine; it is the opposite to curative medicine. Furthermore, hygiene strives to increase efficiency which can only reach its highest point by providing the most favorable living conditions.

The province through which hygiene has to search is tremendous. As a result of the interlocking of all natural processes it encompasses all features of natural science. To these must be added the artificial necessities of life, which in the narrow sense are intimately associated with the natural necessities of life.

Veterinary hygiene or sanitary science is one of the most important branches of medicine. As Vegetius emphasized, the prevention of disease is more important than curing it. It is important for every owner of animals to have some knowledge of sanitary science, particularly if he wishes to benefit to a great extent through his stock raising. It is also very important that the veterinarian keep the animals in good health and prevent diseases, entirely aside from the fact that sanitary measures are absolutely essential in treating diseases and combating epizootics.

The term "hygiene" was used before Galen's time to designate matters relating to the maintenance and continuance of health. The word finds its source in the Greek ὑγίεια, meaning health.

The expression "dietetics," which is still sometimes used for hygiene, does not carry the same significance as this. Dietetics endeavors by means of the regulation of food and drink to maintain the health of healthy individuals and to restore the health of the ailing.

Historical Summary of the Development of Sanitary Science

The first attempts at sanitary science in the way of practical measures for maintaining health can be traced back to early antiquity. A very good survey of the sanitary conditions at that time can be obtained from the extensive works of Ginzrot, Gesner and Schneider.

The East Indians, Assyrians and Babylonians, whose early history dates back to 4500 B. C., built dams with the object of providing a water supply, which even today are regarded as worthy of being used as basic models (Merckel, Bezold). They supplied the water for the land and the homes. Many developments, which thousands of years

later during Greek and Roman times were considered new and peculiar, can be traced back to the Babylonians. Among the Indians there existed a sort of police inspection of the market. Old India is considered as the cradle of smallpox vaccination.

The old Egyptians and Jews had sanitary laws regarding foods, clothing and cleanliness, the combating of leprosy and venereal diseases (circumcision, which was introduced from Egypt to Palestine), etc. In Egypt animals intended for slaughter for food were subjected to inspection before slaughter and had to be marked on the horns to this effect with a seal (Herodotus). The Egyptians had some knowledge of several different intestinal worms. They conducted the waste waters of the cities to the country (Rieselfelder).

The Greeks at an early period had public sanitary rules which were partly influenced by religion (Asklepiaden) and which intimately affected the family life of the Spartans through the efforts of Lycurgus (800 B. C.). Great importance was attached to physical culture (hardening, gymnastic exercises, etc.) throughout Greece. Solon, Pythagoras, Plato and Aristotle also recommended rigid hygienic rules, demanded sanitary officers and caused the construction of public sanitary works (draining swampy parts of cities, installing public sewers, baths, etc.). The writings of Hippocrates on rules for living, air, water and building sites were fruitful and had a lasting effect. Worthy of mention is the attempt at disinfection. When contagious diseases occurred the attempt was made to rid the air of infectious matter by means of the smoke from burning sulphur and by lighting big fires in the streets (Galen). In Athens, on Samos, etc., sewers and sluices were installed. Relative to veterinary hygiene the reader is referred to Aristotle's "Natural History of Animals," in which are found innumerable references to the sanitary care of horses, cattle, swine and dogs. Furthermore, Xenophon is to be mentioned first of all in this connection. References are made, among others, by Homer, Pausanias, Herodotus, Aristophanes, Euripides and Callimachus.

The old Greeks laid great stress upon the care of the skin and hoofs of horses. Xenophon recommended that the cleaning be done outside of the stable. The head, forelock, mane and tail should be washed often; the back and legs should be thoroughly rubbed dry, at which time one should wear coarse woolen gloves without fingers and use many cloths. The remaining parts of the body should be cleaned with an iron or wooden curry-comb. Also, there were in use at that time sweat spatulas made of iron, bone or hard wood. Frequently the horses were led to the river or sea, washed off with a sponge and then carefully dried, curried and brushed until the hair shone; the forelock, mane and tail were combed out, and sometimes oil was applied in order to give them a shiny appearance. Loose flakes of horn on the side of the hoof were filed off, the sole was trimmed and

cleaned out, and a mixture of pitch, wax and animal oil was rubbed into the hoofs.

The stables, which were usually erected near the house, the Greeks provided with mangers. Stable racks were not known at that time. The horses of army commanders when in the field were sheltered under tents or in huts. While the Assyrians still fastened their horses to the mangers with a strap tied to the feet, we find that the Greeks and Romans were using also halters, ropes and chains with which to tie their horses fast. Xenophon recommended that the mangers be cleaned often, that the stables be plastered and flushed out and that the manure and bedding be removed daily. Alongside

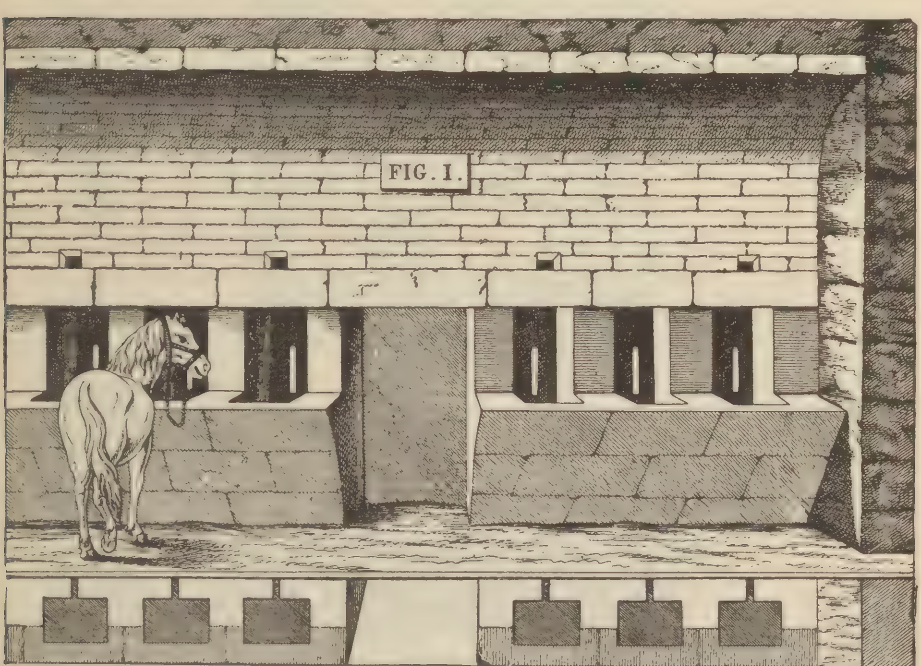

Fig. 1. An Excavated Stable of an Old Grecian Colony near Centorbi in Sicily. (After Ginzrot.)

of the stable the Greeks provided a sandy plot on which the tired horses could rest and wallow.

The feed consisted of spelt, barley, wheat and grass (pasture). Hay and oats as a grain were not yet known. Wherever oats grew wild it was fed green. The Romans, however, cultivated oats and also made and fed hay. They also fed clover (lotus).

A stable dug out by a Greek colony in Centorbi in Sicily is shown in Figures 1 and 2. The stable consists of six stalls, with four-cornered mangers made of masonry, above which was an opening through which presumably the halter strap was drawn. A wider

opening was made beneath in the arch of the ceiling which likewise possibly served for drawing the halter strap through or for ventilation.

Figure 3 represents, according to Xenophon, a reconstructed early

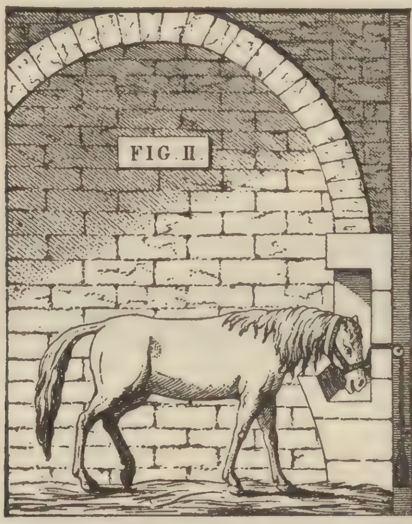

Fig. 2. An Excavated Stable of an Old Grecian Colony near Centorbi in Sicily. (After Ginzrot.)

Greek stall of luxurious type. The explanatory letters accompanying it indicate: A, horse blanket; B, rear strap; C, girth; D, halter ring; E, manger; a, curry comb; b, sponge; c, brush, usually made of palm

Fig. 3. An Old Grecian Luxury Stable reconstructed according Xenophon. (After Ginzrot.)

fibre, less frequently of swine bristles; d, comb; e, sieve, the floor of which was covered with perforated parchment; f, manure fork; g, rake; h, shovel; i, stall bar; k, dust brush made of palm fibre; l, sweat knife.

As to harnessing, vehicles and the manner of shoeing among the old Greeks, Romans, Egyptians, etc., the reader is referred to the well illustrated book of Ginzrot.[1]

Old Rome had excellent plumbing facilities for spring water, the beginning of which dates back to Ancus Marcius (614 B. C.). Aqueducts extended out from the city for 80 kilometers. From 700 springs there was led such a great volume of water into the city that, for example, at the time of Trajan more than 500 liters of water per day were allotted to each inhabitant, which even today would be considered an unusually large quantity; the amount used today in Berlin is only 75 liters per day for each inhabitant. Regarding the water supplies in ancient times the work by Merckel gives more detailed information. Public baths existed in great numbers (from 400 B. C. to 180 A. D. there were ostensibly 800 of them). The pleasure grounds which were arranged with the idea of accommodating a great number of people (for instance, the extremely luxuriously arranged Thermae Caracallae which accommodated 3,000 persons) testify to the national character. The Romans also installed excellent water supplies in their colonies, which in part are still being used today. Among other excellent hygienic measures in old Rome the question of drainage was given satisfactory attention. The waste matter was disposed of through a network of subterranean sewers. It is estimated that in view of the size of this sewer system a cleaning and restoration of it in the second century B. C. would require two million marks (normally $500,000). The centralized heating system, operated by heating the floors, was known in old Rome.

Veterinary hygiene particularly among the Romans was developed to a notable degree. Even Bolus-Medesius (70 B. C.), Publius Vergilius Maro (71-19 B. C.) and Lucius Junius Moduratus Columella (100 A. D.) recommended for the suppression of certain epizootics (anthrax in sheep?) a thorough examination of threatened herds, the immediate slaughter of sick animals and the burial of the carcass with the skin on it. Publius Vegetius Renatus (400 A. D.) alluded in a similar manner to combating glanders among the solipeds, i.e., the isolation of the sick and suspected ones as well as the safe removal (burial) of the animals that died. He fully recognized the great value of the care of health and expressed himself regarding this in the following words: "Melius enim diligenti studio custodire sanitatem, quam aegritudinibus praestare remedia." Moreover he gave instruc-

[1]Ginzrot. Die Wagen und Fahrwerke der Griechen und Rœmer und anderer alten Voelker; nebst der Bespannung, Zaeumung und Verzierung ihrer Zug-, Reit-, und Lasttiere. Muenchen, Cottasche Buchhandlung, 1817.

tions on the arrangement of the stable (floor, mangers, stable racks, lighting and ventilation), the care of the skin and the hoof and how to trim the mane, tail and fetlock, and on the feeding and watering of animals. Among other Roman authors we should mention here Pliny, Pollux, Varro, Palladius and Cato.

Most of the advancements made in hygiene were lost with the fall of the West Roman Empire. The water supplies deteriorated and the cleanliness of public places became neglected. Regarding hygienic measures during the Middle Ages, mention is made of the prohibitory act of Pope Zacharias (communicated through Boniface) that the flesh of sick animals was not to be eaten. Pork or bacon before being eaten had to be cooked or smoked. In Germany the overseers of compulsory labor, the burgrave and magistrates, determined upon innumerable and in part excellent regulations regarding the handling of meat, which can be traced back to the twelfth century. According to the Augusburger state law animals were to be slaughtered in the public slaughterhouse and be inspected. Pumping slaughtered animals full of air was forbidden. Edible meat from sick animals had to be declared as such when sold. The state law in Wimpfen (1404) required that the meat of Finnish animals be brought to a specially prepared counter known as the "Pfinnbank" (Freibank).

A reformation of all branches of science began in the fifteenth century, first in the cosmic researches through Copernicus (born 1473), Galileo (born 1564) and Kepler (born 1571); then in anatomy by Vesal (1543), Fallopio, Eustachio and others; in physiology by Santorius (thermometry and organology, 1571), Harvey (circulatory system, 1628), Mayow (respiration and heart action, 1668), La Bruyére and L. Cornaro (alimentation); chemistry by Paracelsus (1493-1541); also botany, zoology, mineralogy, etc. Bacteriology saw its beginning in the first centuries of modern times (von Helmont, fermentation, 1648; Athanasius Kircher, minute life in glandular pus, air, water, cheese, etc., 1658; Leeuwenhoek, fungi, yeasts, microorganisms in feces, slime from teeth, etc., 1675; Stahl, microorganisms as the cause of fermentation and decay, 1697; Plencziz, microorganisms as the cause of contagious diseases, 1769).

During the Middle Ages the attempts to explain the cause of diseases and epizootics and to combat them were chiefly along religious and mystical lines, and this resulted in a loss of interest in hygienic measures and caused them to be neglected or even forgotten to a large extent. The extraordinarily ravaging diseases of the Middle Ages and even during modern times (Thomas) were combated at all or else only very inadequate measures were employed. As a consequence bubonic plague (black death) in 1346-1353 caused the death of 26 millions of people. Not until the seventeenth century did the authorities begin to quarantine (Albrecht), institute

compulsory notification of diseases, isolation and even destruction of sick animals and the burying of animals which had died of an epizootic, together with the hair and skin. The edicts of the kingdom of Prussia which originated during 1711, 1717, etc., as well as the mandates of the electors of Saxony for averting epizootics (1712, 1716, etc.), are very probably the oldest laws on veterinary hygienic measures. All of these measures were formulated with the thought in mind that epizoötics were disseminated through contagion, and during the time that followed emphasis was brought to bear upon preventing infection and annihilating the infectious matter.

It came to be understood that results could be expected only from general veterinary regulations, regulations formulated from the standpoint of serving all, such as are issued for larger districts, or preferably international regulations. The deliberations of the international veterinary congress (the first one held in 1863) played an important part in effecting such regulations. In Germany the meetings of the German veterinary council (first meeting, 1874) were influential and laid the ground structure for a number of laws.

Toward the close of the eighteenth century (May 14, 1796) one of the most important hygienic accomplishments occurred—vaccination against smallpox by Jenner. During this time Johann Peter Frank worked over and compiled the collective knowledge on hygiene, issuing his work in six volumes, "A System for Thorough Sanitation" ("*System einer vollstaendigen medizinischen Polizei*"), 1784-1819. The well-known master of chemistry, Lavoisier (1768), should also be mentioned as the patron of home hygiene, water supply, the building of canals, ventilation, etc.

Privately conducted veterinary hygiene experienced at this time many improvements through the originality of stable attendants, stable superintendents and farmers. The objects given most consideration were nursing, stable hygiene, harnessing, shoeing and feeding, particularly of the horse. From the rather complete literature of those times we can mention Uffenheim's "The Perfect Horseman" ("*Der vollkommene Pferde-Kenner*"), 1764, which gives a literary perspective dating back to 1575.

Dietetics was first given serious consideration at the time (1762) when veterinary schools were founded. We find that even in the year 1778 Kersting in Hanover lectured on hygiene and in 1790 Sick in Berlin lectured on dietetics, aside from their official duties. Notwithstanding this, hygiene experienced its development very late, after more than a century had been devoted to the development of the fundamental sciences (anatomy, physiology, chemistry, general pathology, etc.). It was only in the province of the study of contagious diseases that a few worth-while advances were made. In 1770 in Hanover the first satisfactory vaccinations against sheep pox were

carried out, after Bourgelat in 1763 had determined the infectiousness of that disease. In 1797 its contagious character was experimentally proved by Abilgaard, the disease having previously been recognized by Absyrtus and Vegetius in the fourth century. The resistance of the infectious matter of certain contagious diseases (rinderpest, contagious pleuro-pneumonia, sheep pox, etc.) in exposed animals, carcasses, stables, feed and bedding, against heat and cold and disinfectants, was determined. In 1804 Walz discovered the parasite causing sheep scab and thereby made it possible to carry out a rational campaign against that disease. In 1852 Willens tested out vaccination against contagious pleuro-pneumonia, which Hausmann had recommended in the beginning of the nineteenth century. We must thank Haubner[2] for the first comprehensive treatise on veterinary hygiene, even though he had predecessors, particularly in the feeding and care of animals, in Riem and Reutter, Abildgaard, Godine, Franz, Ribbe, Kuers, Magne and Koeber. In the later literature there should be mentioned especially Dammann's work on hygiene.[3] Veterinary hygiene also obtained many valuable features from animal husbandry. Of the different phases of hygiene feeds and feeding were at first particularly considered. These subjects were scientifically developed through the work of Thaer (value of hay), J. Mueller, Liebig (theory of the process of nutrition), Pettenkofer and C. Voigt (fundamentals of practical alimentation), Wolff (condition of feeds), Kellner (starch content) and others.

About seventy years ago a scientific investigation into the field of general hygiene was instituted by Pettenkofer, the father of hygiene, as he is often called. He was the first to recognize that health was disturbed, more than was imagined up to that time, by influences of the outer world and not in humans and animals. He laid the groundwork for experimental hygiene by means of his series of experimental researches on ventilation, water supply, the building of canals, the automatic purification of rivers, nutrition, etc.

The discoveries during a later period were the ones which opened new fields of endeavor and made it possible to apply exact research methods to the exceedingly important questions of the origin, diagnosis, dissemination and prevention of infectious diseases. The particularly important discoveries in this connection were those by Bassi (in 1837, the cause of "muscardine" of silkworms), Schoenlein (in 1839, the cause of scabies), De Bary (1842, fodder fungi), Pollender, Davaine and Branell (1849-1855, *Bacillus anthracis*), etc. More important than all, however, were the discoveries of Koch (bacteriology, anthrax bacillus, typhoid fever bacillus, cholera bacillus, tubercle bacillus, tuberculin, etc.), Pasteur (fermentation,

[2]Haubner. Gesundheitspflege der landwirtsch. Haussaeugetiere. (Hygiene of Domestic Animals on the Farm). 1845.

[3]Dammann. Gesundheitspflege der landwirtsch. Haussaeugetiere. 1888.

anthrax vaccination, erysipelas vaccination, rabies vaccination, etc.), von Behring (diphtheria and tetanus antitoxins, etc.), Ehrlich (side-chain theory, salvarsan, etc.), Gruber (agglutination), Uhlenhut (precipitation), Buchner (alexine zymase), Pfeiffer (Pfeiffer's phenomenon), Bordet (complement fixation), Pirquet (allergy), Friedberger (anaphylaxis), etc. In these phases of veterinary hygiene many valuable contributions were furnished by Loeffler and Schuetz (glanders, swine plague, swine erysipelas), Nocard (mastitis streptococci), Johne (botryomycosis, capsule of the anthrax bacillus, grease heel), Bang (abortion, combating tuberculosis), Preisz (swine plague and hog cholera), Arloing (vaccination against blackleg), De Schweinitz and Dorset (hog cholera), Hutyra (vaccination against hog cholera), Kitt (fowl cholera, blackleg), Jensen (calf scour, bradsot, petechial fever), Lorenz (vaccination against erysipelas), Rivolta (fowl cholera), Theobald Smith (hemoglobinuria of cattle), Kitasato (blackleg bacillus) as well as others.

The important discoveries of Kuechenmeister, Leuckart and Zuern, as well as Perroncito's work on animal parasites, occurred at this time and were of fundamental importance in preventing the diseases caused by parasites.

Advances in Hygiene During the Last Few Decades

Hygiene in a comparatively short time has made successful advances which have had their beneficial influence on the collective medical sciences. The practical results are brought into bold relief by means of statistics, particularly in connection with infectious diseases and epidemics and epizoötics.

A successful struggle against most of the epizoötics, including the most dangerous ones, by means of the laws relating to prevention and suppression of epizootics, was not made possible in the entire German Empire until 1880, even though "measures against rinderpest" had been applied in the North German Alliance since 1869 and in the entire German Empire since 1872.

The results of hygienic teachings and hygienic measures, which have been obtained in combating rinderpest, contagious pleuro-pneumonia of cattle, sheep pox and glanders since this time are unmistakable. Rinderpest, which again spread over more territory in Germany in 1870-71, was soon eradicated. In 1877-78 it reappeared but was completely eradicated within a short time, as also when it recurred in 1881. Since that time the German Empire has been free from this disease.[1]

The struggle against sheep pox was equally successful, it being rampant in East Prussia in 1886, when the compiling of statistics was begun. Aside from such instances where the disease was introduced

[1] In 1920-1921 there was another outbreak of rinderpest in Germany, which it is believed was introduced by way of Belgium, which latter country traced the outbreak to some cattle shipped in from the orient.—Translator's note.

from other countries during 1888, 1900-1901 and 1903-1908, Germany has not had any recurrences.

Contagious pleuro-pneumonia could also be considered as being eradicated during the last few years before the great war. In 1887 there were 1,317 cases for every 10,000 cattle. In 1903-1906 this disease was practically unknown, but in 1907-1908 a mild recurrence appeared (about 0.22 cases for every 10,000 cattle). During 1909-1910 the country was almost free and in 1911 it was entirely free from contagious pleuro-pneumonia and remained so until the outbreak of the war. During the war, due to the introduction of foreign cattle (Roumanian draft oxen), the disease again spread through the German Empire.

Glanders has consistently decreased, with the exception of slight exacerbations, since 1889, when 3.8 cases existed for every 10,000 horses, to 1914, when 0.5 cases existed for every 10,000 horses. During the war glanders became markedly on the increase.

The results obtained in the struggle of the last few years against foot-and-mouth disease are still very questionable. This disease spread very rapidly during 1892, 1899 and particularly in 1911, when the high number of 3,366,369 cases developed among cattle, the largest number observed since the date (1886) when the compilation of statistics on the occurrence of diseases was begun. The disease practically disappeared in 1912 and 1913, but in 1914 it again caused 1,400,000 cases. During the remaining years of the last decades the prevalence of the disease was comparatively light. The sudden increase which developed in the years previously mentioned, where the measures instituted totally failed, is due to the extraordinarily contagious character of foot-and-mouth disease and the rapid decrease in immunity of those susceptible animals which survive an attack.

Fowl cholera decreased from its highest number of cases, 83,000, in 1903 to 4,727 in 1914.

We have not made any substantial advance since 1886 in the struggle against rabies, scabies of horses and sheep, vesicular exanthema of horses and cattle, swine erysipelas, hog cholera and swine plague. It is only against rabies that some success has been attained during the last years. This disease decreased from 775 cases among dogs in 1909 to 190 in 1914. Mange among horses spread very noticeably during the war.

In spite of the measures instituted, anthrax and blackleg have increased. Anthrax has especially been on the increase among swine during the last two years of peace (1919-1920). The struggle against anthrax and blackleg would give more fruitful results if the prevailing custom of burying the carcass were entirely discontinued and in its stead the carcass as well as all infected material involved were

burned or shipped to the modern skinning establishments and tanneries where the carcasses are subjected to heat.

Regarding tuberculosis, results from a general standpoint have as yet not been attained; in fact the bovine type, which causes such great damage among stock, has been on the increase from year to year. The decrease which appeared during the war was only an apparent one and is really only the result of the increased slaughtering which occurred at that time and was only a temporary abatement. The spread of tuberculosis is not to be blamed so much on the impotence of hygiene as on the insufficient application of the practical, feasible and fruitful hygienic measures of which we will here mention only the Bang method and the Klimmer method. It has been shown that where suitable and appropriate measures were instituted, it has been possible to decrease substantially tuberculosis among cattle and in fact to eradicate it entirely. (Klimmer[2].)

We not only have an objective means of measuring the practical results obtainable through the application of hygiene in the morbidity and mortality figures on infectious diseases, but this can be brought out very emphatically by the increased efficiency obtainable from the domestic animals through proper hygienic conditions. It can be definitely established that efficiency is increased through bettering the hygienic conditions of the animals.

A quantitative estimation of efficiency is easily made as regards milk production. In this connection Backhaus determined that by means of a properly carried out treatment of the skin of milk cows the daily yield of milk from one cow could be increased 1 liter (1 quart). According to experiments conducted in Wuerttemberg the relative and absolute fat content of the milk could be increased in cattle which spent their life in the stable by exercising them for an hour in the fresh air. According to Stockmayer, the annual milk yield of every cow in a certain model stable was increased 483 liters (120.75 gallons) by simply installing a better ventilating system, although the same kind of feed was continued. Huntemann reports that the average daily quantity of milk was increased 1⅜ liters through supplying a sufficient quantity of good drinking water (automatic watering system), and also that the quantity and the quality of the water had a marked influence on the general condition of the animals (meat production). These examples, whose number could easily be increased, plainly show that the application of hygienic measures is not only valuable in that they cause a decrease in losses through the reduction of the morbidity and the mortality rate, but is also very evident in the increase of efficiency which follows and which often alone amply pays for itself.

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[2] Klimmer. Tuberkulosebekaempfung im Handbuch der Serumtherapie und Serumdiagnostik, herausgegeben von Klimmer und Wolff-Eisner, Leipzig, 1911, p. 124.

Section I

The Atmosphere

Air is absolutely essential for the life of domestic animals. Oxygen is taken from the air and carbonic acid and water are given off by means of breathing. The air also plays an important part in reducing the temperature of the body. The chemical composition and the physical properties of the air influence the health and well-being in several ways. The dust and excitants of disease contained in the air may endanger the health.

A. Constituents of the Air

I. The Gaseous Constituents of the Air

Atmospheric air, when freed of its varying water content, shows a composition which is almost invariably the same, namely, in volume percentage: Nitrogen, 78.03; oxygen, 21.00; carbonic acid, 0.03; argon 0.94. Furthermore, there are traces of neon, helium, krypton, xenon and hydrogen, as well as variable traces of ozone, hydrogen peroxide, ammonia, nitric acid and nitrous acid.

Aside from these, other gases may become mixed with the air wherever they occur (hydrocarbons, sulphurous acid, sulphuretted hydrogen, carbon monoxide, etc.). It is impossible for these gases to have a wide distribution in the open, since they originate only in certain places and are constantly being removed from the air as result of precipitation and oxidation processes.

1. Nitrogen, Argon, Krypton, Neon, Helium and Xenon.

These indifferent gases rarefy the oxygen to a certain extent. Where the oxygen content of the air is sufficient they have no hygienic significance.

2. Oxygen, Ozone and Hydrogen Peroxide.

The percentage of oxygen in free air is very constant at certain times and altitudes (21 per cent according to volume), in spite of the fact that great quantities of oxygen are constantly consumed by the animal life as well as through other constantly occurring oxidation processes in nature, extremely large quantities being consumed on the earth as a whole (20 cubic kilometers daily). The reasons for this constancy are the extraordinarily large reserve of oxygen in the entire atmosphere, the production of oxygen by the plants containing chlorophyll and the mixing of the air by means of air currents. The

variations in the oxygen content amount to only 0.5 per cent. For the most part the air in manufacturing cities hardly shows any appreciable differences from the air in the country and in the forest. These insignificant differences in the oxygen content of free atmosphere have no hygienic importance.

During quiet breathing about 2.7 per cent (horse) to 5 per cent (man) of oxygen is removed from the air (consult section on the stable, chapter on ventilation—the necessity of fresh air), and it is chiefly combined chemically with the hemoglobin and only a very small amount of it taken up by the blood plasma. Chemical union between oxygen and hemoglobin still occurs when half the normal amount of oxygen is available. Because of this fact it is possible for us to withstand practically without any inconvenience a beginning diminution of oxygen. When there is a somewhat more marked impoverishment of oxygen, the body attempts to adjust itself to the temporary deficiency by means of deep and rapid breathing and increased heart action.

When the air contains less than 11 per cent oxygen dyspnea develops, and if less than 7 per cent death occurs. Such marked deficiencies in oxygen practically very seldom occur among our animals (as in shipping animals in entirely closed freight cars, especially crowding of the cars, also crowding of sheep in a stable after shearing). It is generally believed, and with reason, that a prolonged stay in an atmosphere moderately poor in oxygen has a deleterious affect on the general condition and assimilation of the body; this, however, as yet is not sufficiently explained (refer to ventilation, stable hygiene).

The determination of the oxygen content of the air is very seldom done for any hygienic reason. It can be done by absorption, absorbing the oxygen from a quantity of air in a closed graduated burette by means of pyrogallic acid with the addition of potassium hydroxide or by means of yellow phosphorus or hydrosulphite solution. (See the works of Bunsen, Hempel and Winkler on gas analysis.)

Ozone (active oxygen), O_3, and hydrogen peroxide, H_2O_2, occur in free air only to a limited extent (2 milligrams in 100 cubic meters of air), and not at all in large cities, inhabited rooms and stables. They develop through excessive vaporization of water (salt works, seaside, moist meadows, etc.), electrical discharges and where oxidation processes are conducted on a large scale.

Ozone has a marked oxidizing action, whereas hydrogen peroxide is weaker in this respect. When in strong concentrations (14 milligrams of ozone to 1 liter of air) they are very effective disinfectants. In the dilution in which they occur in the atmosphere they do not destroy microorganisms, neither are they capable of influencing the state of health of man or animals. If a hygienic significance may be ascribed to them, this would consist in the cleansing of the air of organic substances and other oxidizable gases.

In order to prove and determine the presence of atmospheric ozone and hydrogen peroxide, starch-potassium-iodide paper was formerly employed (Schoenbein's ozonometer) and Houzeau's method. Today the determination of the oxidizing ability of the air (of the ozone) is preferably done by using

tetra (methylparaphenylendiamino) papers according to Wurster. The colorless tetra paper is first colored violet by the ozone, but when six times the quantity of ozone is added it is again rendered colorless. The manner of procedure in this method of determining ozone is as follows: The tetra paper is tightly drawn over one end of a glass tube having the diameter of 0.6 cm. If the air is damp it is moistened with water, and if dry it is moistened with glycerin. To the other end of the glass tube is attached a standardized suction apparatus by means of which air is drawn to the tetra paper. Usually 5 to 20 liters of air are sufficient to produce a distinct coloring of the paper. The spot which results is moistened with diluted glycerin and compared with the color scale made for this purpose, from which the ozone content of the air is determined.

3. Carbonic Acid.

The carbonic acid content of the open air varies very little. The extremes that have been noted are 0.26 and 0.56 per cent. The average carbonic acid content in the country is 0.30 per cent and in the cities 0.37 per cent. In inhabitated stables or other buildings where strong constant ventilation is more or less lacking the carbonic acid content can become considerably increased (1, 2 and even 10 per cent). (See "The Stable," under "Ventilation.")

As sources for carbonic acid there are to be considered: (**a**) Respiration of man and animals (a man produces at rest about 20 liters an hour, and a cow or horse about 100 to 125 liters an hour); (**b**) decay and decomposition processes, which occur mostly in the manure; (**c**) the burning of light and fuel materials (in industrial regions this is particularly true where there is an annual carbonic acid production of about 400 billion cubic meters as compared with the annual carbonic acid production of the entire human population of the earth by means of respiration of perhaps 130 billion cubic meters); (**d**) the subterranean accumulations of carbonic acid which are connected with the atmosphere (vaporous caverns near Pyrmont, crater basin of Eifel, "Hundsgrotte" near Neapel).

The higher specific gravity of carbonic acid in contrast to that of ordinary air is no hindrance to the mixing of the carbonic acid and the higher air strata even in closed rooms if sufficient cause exists to produce movements of the air (1 liter CO_2 at 0° C. and 760 mm. pressure weighs 1,977 grams; 1 liter O equals 1,429 gm.; 1 liter N equals 1,259 gm.; 1 liter air equals 1,293 gm.). For example, the insignificant heating of the air from the warm-blooded body will suffice as such a cause.

Carbonic acid is removed from the atmosphere (**a**) by the plants, which utilize it and release oxygen at the same time (example: $6CO_2+6H_2O=C_6H_{12}O_6+6O_2$); (**b**) through precipitations, which on the average have the ability to absorb 2 c.c. carbonic acid in 1 liter; (**c**) by forming inorganic carbonic acid compounds (carbonates).

The carbonic acid content of the atmosphere of inhabited rooms serves very often as a means of measuring the extent of air pollution which may exist. Therefore it is valuable from a hygienic standpoint to know simple and accurate methods for the **determination of carbonic acid.** The most excellent procedure is the quantitative analytical method of Pettenkofer, which is done in the following manner:

A large bottle of known capacity (about 5 liters) is filled by means of a bellows with the air to be examined, care being taken that the exhaled air of the operator does not enter into it and in that way interfere with the results. At the same time the temperature and the atmospheric pressure are ascertained. Then 50 c.c. baryta water is added to the bottle, which is then stoppered with a paraffined stopper and thoroughly and repeatedly shaken. In fifteen minutes to half an hour the CO_2 is bound. The carbonic acid of the

Note:—c.c.=abbreviation for cubic centimeters.—Translator.

atmosphere combines with the barium hydroxide in the manner shown in the following chemical equation:

$$Ba(OH)_2 + CO2 = BaCO_3 + H2O$$

The fluid which results in the bottle is cloudy, due to the formation of insoluble carbonate of baryta. The bottle is then taken to an open window or out into the open and quickly poured into a narrow glass cylinder which is supplied with a ground glass stopper. After the carbonate of baryta has settled, 10 c.c. of the clear supernatant fluid is removed with a pipette and placed in a beaker; 1 to 2 drops of phenol-phthalein solution (1:50 in alcohol) is then added to this, and oxalic acid (1,405:1000 distilled water) thereupon slowly added drop by drop until the fluid which had changed to red through the addition of the phenol-phthalein becomes colorless. The amount of oxalic acid used is then read. In the same manner one determines the amount of oxalic acid necessary to neutralize 10 c.c. baryta water similar to that previously used but which had not been shaken with air containing carbonic acid. In this second titration it is of course necessary to add a larger quantity of oxalic acid, just as much more as there was barium hydroxide precipitated through the carbonic acid in the first experiment. One c.c. of the oxalic acid referred to corresponds to 0.25 c.c. carbonic acid at 0° C. and 760 mm. pressure. The difference in cubic centimeters of oxalic acid used is to be multiplied by 0.25 and by 5 (originally 50 c.c. of baryta water were poured into the bottle, but only one-fifth of this was used in the titration); the resulting product is the amount of carbonic acid (at O° C. and normal barometric height) in the quantity of air examined. When exact determinations are being made the volume of the air to be examined is also to be reduced to 0° C. and 760 mm. pressure. This is done according to the formula $V_0 = \frac{V \times B}{(1+0.003665\ t)\ 760}$, the V_0 representing the reduced volume of air which is sought, V the measured volume of the bottle, B the barometric reading, t the temperature.

Bitter recommends strontium hydrate water in place of baryta water, and he titrates it with sulfuric acid (1.093 gm. in 1,000 H_2O) and phenolphthalein as an indicator. The end reaction is more sharply defined and is not disturbed through a reappearance of the red color.

Inasmuch as Pettenkofer's volumetric analytical method is somewhat detailed and bothersome, some shorter procedures have been devised, of which that of Wolpert is one of the better ones. It is as follows: There are placed into a cylinder (such as shown in Fig. 4), after the removal of the plunger, 2 c.c. of a O.2 per cent solution of crystallized soda colored red with phenolphthalein; the plunger is then replaced in the cylinder to "extremely bad" (marked on the cylinder "Aeusserst schlecht") and the entire apparatus shaken one minute, which is also done each time the plunger's position is changed. If the test solution remains red, the plunger is drawn upward a little at a time (the handle of the plunger is hollow) shaking for one minute at each change of position, until finally decolorization has taken place. The scale marked on the cylinder makes it possible to read the carbonic acid content and the degree of purity of the air. The minimetric procedure of Lunge-Zeckendorf depends on the same principle, which, however, can not be directly used on stable air, which has a higher carbonic acid content than ordinary air.

Hygienic Significance. Carbonic acid of the air does not have a deleterious influence on health until the carbonic acid content of inspired air is above 4 per cent; even 5 per cent can be withstood temporarily without harm. When more than 18 per cent of the gas is present death can occur at any moment, provided that the carbonic acid has accumulated at the expense of the oxygen, in which case, however, it is then the deficiency in oxygen and not the accumulation of carbonic acid that is the noxious factor. Gaertner showed that rabbits would remain alive half an hour in an atmosphere consisting of 80 per cent (!) CO_2 and 20 per cent O.

In veterinary literature there are a few individual cases of acute poisoning resulting from an accumulation of carbonic acid, or rather a deficiency in oxygen (such as the shipment of live stock in entirely closed freight cars, especially when too many are placed in the car; crowding of sheep in the stable after shearing, etc.). However, such intances of poisoning occur very seldom and are easily avoidable. The sick animals should be taken into the fresh air and in certain cases artificial respiration resorted to.

Chronic cases of poisoning might occur more frequently. Domestic animals on the farm, particularly cattle, are frequently forced to stay, often for long periods of time, in a poorly ventilated, crowded stable, standing on great quantities of accumulated manure which is undergoing rapid decomposition and giving off volumes of carbonic acid and other injurious gases. In winter all holes, fissures and

Fig. 4. Wolpert's Karbazidometer (for testing air for carbonic acid).

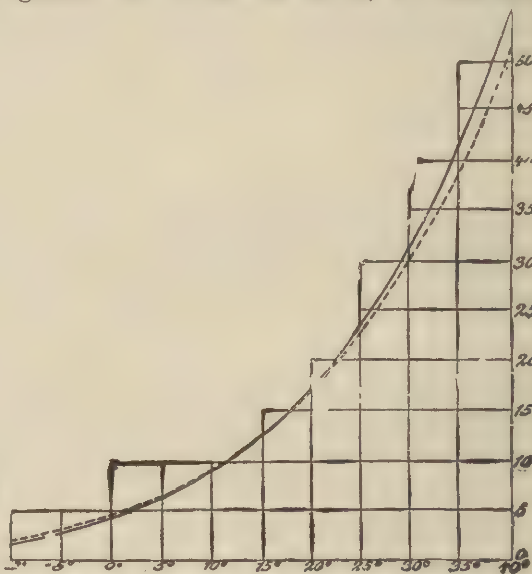

Fig. 5. Water capacity in the air from 10 to 40°C.

cracks around windows and doors are often closed as tightly as possible under the misapprehension that the animals have to be protected against every draft and possibility of catching cold. The natural results are that the air will be deficient in oxygen and contain an excess of carbonic acid. Even though the percentage content of these gases does not change to the extent of producing acute poisoning, nevertheless in time they will cause a depressed respiration (Wolpert), poorer aeration of the lungs, and in that way make the lungs more susceptible to disease (infectious bacteria), a lowering of the state of nutrition and health of the animals (Seegert) as well as a lowering of their efficiency, especially in regard to their

milk production (see page 21 and the section on "The Stable and Ventilation").

This action is assisted through *gaseous organic matter* which originates from the skin, and intestinal gases, and whose action is more annoying and nauseating than directly harmful to health. Brown Séquard and d'Arsonval as well as Weichardt more recently assume that with the expired air there are given forth poisonous substances, a poison causing fatigue, kenotoxin of Weichardt. There are those who very positively disagree with this view, e. g., Luebbert and Peters, Fluegge, Paul, Inaba, Formánck and others. Irrefutable proof of the presence of poisonous substances in expired air has not yet been advanced.

These organic gaseous excretory products are, according to Pettenkofer, related to a certain extent to carbonic acid. In this sense the carbonic acid content can also be used as a criterion in determining air pollution by these gaseous products. According to Pettenkofer, the air in a room where individuals are to remain indefinitely should not contain more than 1 per cent of expired carbonic acid gas and should not smell bad. Such requirements, however, can not be applied to stable air. A certain odor will exist in spite of the most painstaking cleanliness and best ventilation. Relative to the carbonic acid content of stable air, Maercker says there may exist 2.5 to 3 per cent carbonic acid and the air still be healthy and normal. When over 3 per cent it is as a rule polluted and damp, and 4 per cent must be the extreme limit permitted. (See "The Stable and Ventilation.")

4. Water Vapor (Atmospheric Moisture).

The atmosphere constantly contains certain quantities of water in a gaseous state (water vapor).

The ability to take up water decreases with the temperature, but air having a temperature below 0° C. is still able to take up very considerable quantities of water. The accompanying curve (Fig. 5) shows, by means of the dotted line, how many grams of water 1 cubic meter of air was able to take up at temperatures ranging from —10° to +40° C. (maximum humidity or water capacity). The solid line indicates the tension of the water vapor in millimeters of mercury. The existing water content of the air is called the "absolute humidity." On the other hand the "relative humidity" (moisture percentage) expresses in percentage the ratio of the absolute water content to the maximum of saturation. For instance, if 1 cubic meter of air at 20° C. contains 4.876 grams of water, and 1 cubic meter of air at 0° C. the same quantity of water, then both have the same absolute humidity, that is, 4.876 grams water in 1 cubic meter. In contrast to this their relative humidity is entirely different. One cubic meter of air at 20° C. is able to take up 17.180 grams of water, but of this it only contains 4.876 grams, therefore its relative humidity is 28 per cent—it is very dry. On the other hand, the air mentioned at 0° C. may nevertheless be able to take up only 4.876 grams of water per cubic meter and is therefore saturated. Its relative humidity would therefore amount to 100 per cent—it is very damp. The saturation deficit is the difference between the maximum and the absolute humidity.

If air saturated with water is cooled, thereby reducing its ability to hold water, there is formed around the finest dust particles floating in the air a

precipitate of water (fog, clouds). If the drops combine they will fall to earth as rain or snow or hail. On cloudless nights the warmth from the earth radiates into space. Objects having a great surface but of limited mass (grasses, leaves, etc.) cool off mostly and the immediately surrounding air is thereby necessarily cooled off to such an extent that it can not entirely hold the water it contains, but will precipitate it on the grass, etc., as dew or hoar frost.

Fig. 6. Hair Hygrometer.

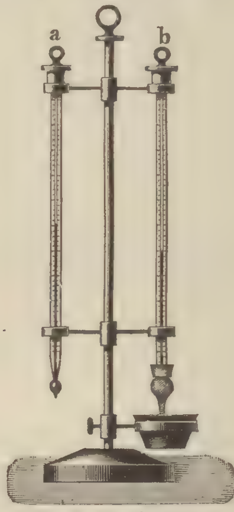

Fig. 7. Psychrometer.

The *determination of the humidity* can be made as follows: (1) By weighing the water vapor of a measured volume of air after absorption by means of sulfuric acid or calcium chloride; (2) by determination of the dew point with the aid of a condensation hygrometer. In hygiene one uses mostly (3) the hair hygrometer or (4) the psychrometer.

The hair hygrometer's action is dependent upon the fact that certain hygroscopic bodies—particularly the fat-freed human hair—become distended during a rising relative humidity and shrink in dry air. The hair is suspended by its upper end in a frame (see Fig. 6) and the lower end is passed around a roller to which a pointer bearing a small weight is attached. The empirically graduated scale indicates the relative humidity of the air. The instrument may vary at times and must be corrected with the aid of a moistened muslin hood.

The psychrometer (which measures cold and dampness) is based on the relation of the cold, due to evaporation, to the relative humidity. The drier the air the more rapidly will the water evaporate and thus produce proportionately greater cold due to evaporation. The method of procedure is as follows: The temperature of the air is determined with a dry thermometer and then with a thermometer whose bulb is covered with muslin moistened with water (Fig. 7). The temperature indicated on the wet-bulb thermometer will be just so much lower in comparison with the dry thermometer as is the drying action of the air. The difference in the temperatures is referred to as the "psychrometric difference." This is also influenced by the velocity of the air. This source of error can be satisfactorily excluded, for hygienic examinations, by rapidly swinging in a circle the wet-bulb thermometer on the end of a string about one yard long until the mercury has reached its lowest point (centrifugal psychrometer). The humidity can be determined from the readings of both thermometers with the aid of a table or can be computed according to the following formula: $e = e' - 0.5\,(t - t^1)\,\frac{b}{755}$. In this formula e represents the vapor tension which is sought, t the temperature of the dry thermometer, t^1

the temperature of the moistened thermometer, e′ the maximal vapor tension of temperature t^1 and b the existing atmospheric pressure.

The following data have been obtained from the observations made on humidity (see Fig. 8): Absolute humidity attains its minimum as a rule in January with 3.9 grams of water to 1 cubic meter of atmosphere, and its maximum in July and August with 10.4 grams of water. Relative humidity acts in an opposite manner. On the average it is 75 to 85 per cent in winter and 65 to 75 per cent in the summer. The smallest percentages (20 to 40) occur in the spring and summer at noon when the wind is from the east. The hour of the day also influences the percentage of humidity. The

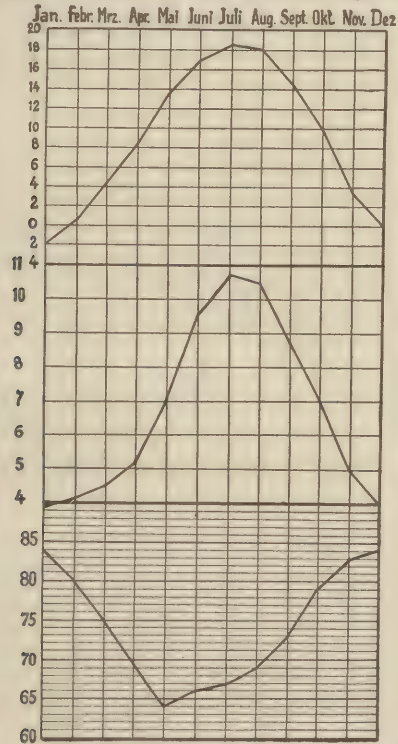

Fig. 8. Annual Course of the Temperature (upper curve) of the absolute humidity content expressed by means of vapor pressure in millimeters of Hg (middle curve) and the relative humidity in percentages (lower curve) of the air in Berlin.

maximum, about 95 per cent, comes at sunrise; the minimum of 50 to 60 per cent between 2 and 4 p. m. Cities in close proximity to large bodies of water show a higher humidity than those in the interior. (The average relative humidity at Kiel is 82 per cent and at Borkum 86 per cent; at Berlin it is 74 per cent and at Vienna 72 per cent.)

Hygienic Significance of Humidity. The drying action of the atmosphere (dryness), which is dependent on the amount of the

saturation deficit and also on the movements of the air, influences in part the formation of dust and also the destruction of pathogenic bacteria. Since great dryness usually occurs when the skies are clear, the disinfecting action of dryness and that from light go together. The humidity of the air furthermore influences the excretion of watery vapor from the living body and in that way also the heat regulation of the body.

It is well known that the regulation of the body heat rests on the fact that heat production and heat loss readily adjust themselves to existing conditions, even within wide limits.

The total heat loss during 24 hours for every 500 kg. (1102.3 lbs.) of live weight of ox., which has been fed sufficiently to maintain health and has lived quietly in the stable, amounts to 18,600 calories; in the case of a horse which has been moderately worked, 24,500 calories, a horse given the average amount of work, 30,000 calories, and if worked hard, 37,000 calories; well-bred sheep, 27,700 calories; brood sows, 35,000 calories. The total amount of heat loss from one horse during an outside temperature of 15° C. is proportioned as follows: Heat radiation, 64 per cent; heat current and heat conduction, 6 to 8 per cent; warming of food and inspired air, about 6 per cent; water vaporization in the respiratory tract, about 10 per cent, and on the skin 15 per cent. When the outside temperature is higher heat radiation and heat conduction are substantially lowered and the loss from water evaporation is increased.

The excretion of water vapor takes place partly from the skin (in man 600 c.c. of water per day, but in domestic animals decidedly less) and partly from the respiratory tract (daily 300 c.c. water from man). It is influenced by the relative humidity[1] and the atmospheric temperature. The excretion of water increases at 15° C. and below as a result of the increase of water evaporation in the respiratory tract. (The cooler air which is to be warmed in the respiratory organs to about blood temperature and be saturated with water vapor possesses a lesser relative humidity.) When the temperature is more than 15° C., and in fact at 25° C. and upward, the excretion of water increases as a sharp curve through the skin excretion. The minimum of water vapor excretion occurs at 15° C. Wind considerably reduces the excretion of water from the skin at 20° to 23° C.; not until the temperature is very high does it increase it.

Muscular exercise and nutrition exert a great influence on the excretion of water vapor; the former exerts the greatest influence in this respect.

Under ordinary conditions the greatest heat is given off through radiation and is influenced by the temperature of the surroundings and not of the air. If the surrounding objects are very cold, much heat will be withdrawn from the animals through radiation in spite of warm air and diseases due to chilling may result. Conversely, a heat stasis can develop under identical conditions when heat radiation is hindered (as by the crowding of animals). This would not result if radiation of the heat could continue uninterruptedly.

As a general rule the excessive excretion of water vapor is better withstood by the body than is the arresting of this function. The

[1]The following example will show to what an unusual degree the excretion of water through evaporation is influenced by the relative humidity. A man weighing 58 kg. (127.86 lbs.) excretes water as water vapor in one hour as follows:

	Dry Air		Moist Air	
Temperature (° C.)	Relative Humidity (per cent)	Excreted Water Vapor Grams	Relative Humidity (per cent)	Excreted Water Vapor Grams
15	8	36.3	89	9.0
20	5	54.1	82	15.3
25	6	75.4	81	23.9
29	6	105.3		

former usually leads only to an increased thirst; very rarely does a serious disturbance of health result. When one-fifth of the total amount of water in the body is given off death occurs (see section on "Water"). In contrast to this, an arrest of the excretion of water vapor at higher temperatures easily results in a heat stasis, which not only weakens the vital energy and become troublesome but may also become serious (See "Heat Stroke," page 41; Cerebral and Pulmonary Congestion). Heat stasis can occur at 24° C. and 70 to 80 per cent humidity, particularly at the time of muscular exercise and if highly nutritious food is eaten. Moist air, as compared with dry, increases heat loss at temperatures below 15° C. through increased heat radiation and conduction; in this manner 12.5 per cent humidity corresponds to each degree of temperature. Extremely dry air has little effect at low temperatures; at higher temperatures it promotes heat loss in a very advantageous manner. Increased dust formation in this connection is a disadvantage, as is also an excessive drying of the uncovered skin and of the exposed superficial mucous membranes in warmer climates. A humidity of 40 to 70 per cent seems to be the most favorable at 18 to 20° C. with rest, normal nutrition and no air movements; at higher temperatures, 30 to 40 per cent; during physical exercise and a temperature of 15° C., about 70 per cent at 18 to 20° C., about 30 to 50 per cent. Stable air is very frequently extraordinarily moist (90 per cent humidity), especially during the colder season as a result of the apparently intentional suppression of ventilation. A protracted stay in air which is almost saturated with water is harmful to health. The animals become soft and debilitated, and are exposed to an increased possibility of infection, since pathogenic bacteria remain infective for a greater length of time in places containing moist air of this character, which precludes the disinfecting action of dryness. The course of diseases also seems to be more difficult (see "The Stable; Ventilation").

5. Other Gaseous Constituents of the Atmosphere.

a. Ammonia, Nitrous Acid and Nitric Acid.

Ammonia (NH_3) arises particularly from the decomposition of constituents containing nitrogen (especially urea in stables). Nitrous acid (HNO_2) and nitric acid (HNO_3) arise from the oxidation of ammonia brought about through the action of certain microorganisms (nitrifying bacteria—bacteria that change ammonia to nitrous and nitric acid) as well as from ozone or directly from nitrogen, oxygen and steam through lightning.

Hygienic Significance. Ammonia often occurs to such a great extent (0.5 to 1 per cent), particularly in horse stables which have inadequate ventilation, that it irritates the conjunctival and respiratory mucous membranes, whereas the previously named gases in the

free atmosphere from where they are removed by precipitates occur only in very limited quantities (in 1 cubic meter of air, 0.1 to 55mg. NH_3; HNO_2 and HNO_3 at the most only traces), so that they do not interfere with health. Polluted air of this kind is readily noticed by its disagreeable, stinging odor. A slight amount of ammonia such as 0.5 per cent is harmless, whereas 1 per cent after prolonged action is harmful and 5 per cent requires but a short time to prove injurious.

In order *to detect ammonia* in the atmoshere, paper strips impregnated with curcuma (turmeric) or nitrate of mercurous oxide are exposed to the air to be examined. Ammonia colors curcuma paper brown and mercury paper black ($Hg_2 . NH_2 . NO_3$), which can be discolored by dropping on hydrochloric acid (Hg_2Cl_2).

For the *determination of ammonia* in the air a certain quantity of the air is drawn through water and the ammonia content of the water is then determined with Nessler's reagent (see directions for the determination of ammonia in water, page ——). Or the air may be conducted through an absorption tube containing $\frac{N}{10}$ sulphuric acid. The determination may also be made technically in the same manner as in Pettenkofer's method for the determination of carbonic acid. A 10-liter bottle is filled with the air to be examined; to it are then added 50 c.c. 1/10 normal sulphuric acid[2] (4.9 gm. to 1 liter distilled water); the bottle is securely stoppered and thoroughly shaken. Then 20 c.c. of the 1/10 normal sulphuric acid is withdrawn and a few drops of neutral rosolic acid solution mixed with it, and to this 1/10 normal ammonia solution (1.7 gm. NH_3 to 1 liter of distilled water) is then carefully added drop by drop until the yellow color begins to turn red. While 20 c.c. 1/10 normal sulphuric acid with 20 c.c. 1/10 normal ammonia solution will exactly show the above-mentioned color change, the same quantity of 1/10 normal sulphuric acid, which was previously shaken with the air containing ammonia, will of course need just so much less ammonia solution to produce this color reaction as there is ammonia gas in the amount of air to be examined. Then from the smallest amount found to be necessary the amount of ammonia gas in the air may be easily calculated. One c.c. 1/10 normal ammonia solution contains 1.7 mg. ammonia.

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[2]The chemist does not as a rule work with such and such a percentage, but instead uses 1, 1/2, 1/10, 1/100, etc., normal (N) solutions. A normal solution is one in which the combined molecular weight by valence in grams of the substance is contained in 1 liter.

	Formula	Molecular Weight		Valence	Equivalent Weight
Hydrochloric acid.......	HCl	1+35.5	= 36.5	1	36.5
Nitric acid.............	HNO_3	1+14+48	= 63	1	63
Sulphuric acid..........	H_2SO_4	2+32+64	= 98	2	49
Oxalic acid.............	$H_2C_2O_4+2H_2O$	2+24+64+4+32	=126	2	63
Phosphoric acid.........	H_3PO_4	3+31+64	= 98	3	32.667
Potassium hydrate.......	KOH	39+16+ 1	= 56	1	56
Sodium hydroxide.......	$NaOH$	23+16+ 1	= 40	1	40
Ammonia...............	NH_3	14+ 3	= 17	1	17
Calcium hydroxide......	$Ca(OH)_2$	40+32+ 2	= 74	2	37
Sodium chloride.........	$NaCl$	23+35.5	= 58.5	1	58.5
Silver nitrate...........	$AgNO_3$	108+14+48	=170	1	170

Since the various chemical substances undergo new combinations among themselves in proportion to their equivalent weights, it is readily understood how practical the normal solution is. One c.c. of N-hydrochloric acid corresponds exactly to any other N-solution of acid (nitric acid, sulphuric acid, phosphoric acid) or to 1 cc. of any other N-solution of a base (potassium hydroxide, sodium hydroxide, etc.), or 1 cc. 1/100 N-oxalic acid = 1 cc. 1/100 potassium permanganate solution. If the solutions were made according to percentage, very tedious figuring would be necessary.

b. Hydrocarbons; Carbon Monoxide, Coal Gas; Hydrogen Sulphide, Sewer Gas; Sulphurous Acid, Smelter Smoke.

Hydrocarbons (methane, etc.) originate through the decomposition of organic matter (especially cellulose) when air is excluded. Under ordinary conditions these gases are of no importance from a hygienic standpoint.

Carbon monoxide arises from the incomplete combustion of coal and occurs in illuminating gas (coal gas), whose poisonous character is due to the presence of carbon monoxide. Its decidedly poisonous character depends on the fact that it firmly combines with the hemoglobin, which is thereby rendered incapable of taking up oxygen. The result is suffocation. When 0.06 per cent carbon monoxide is present it is harmful; 0.4 per cent is fatal.

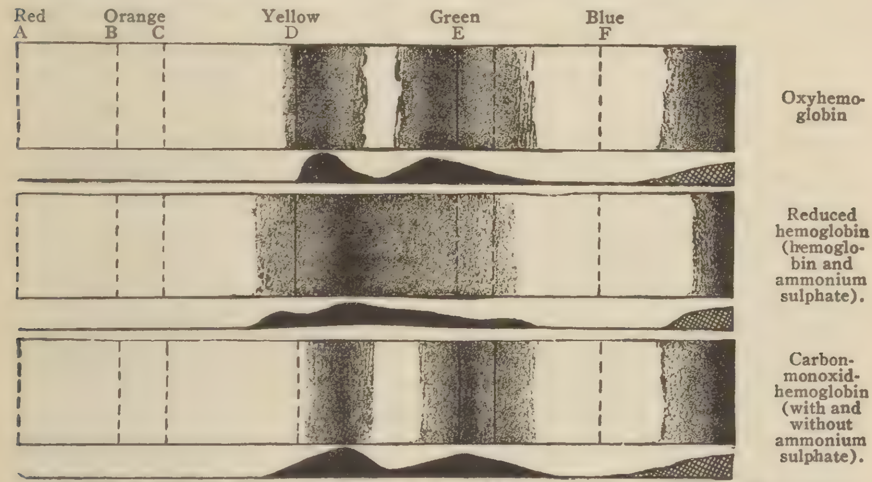

Fig. 9. Absorption Spectrum of oxy-hemoglobin reduced hemoglobin and carbon-monoxid hemoglobin.

The poisoning of domestic animals by carbon monoxide, i. e., coal gas, is rare. Most cases of poisoning of this character can be traced to the backflowing of the gases of combustion from the stove, to a leaking chimney or to gas plumbing leaks. Ordinary illuminating gas contains 5 to 10 per cent of carbon monoxide; water gas, 30 per cent. There have been cases of carbon monoxide poisoning reported in horses, dogs and cattle. Affected animals are to be taken where fresh air can be had; artificial respiration should be supplied.

Detecting Carbon Monoxide: Five to 10 liters of the air to be examined is caught in a bottle to which is then added 10 c.c. of diluted blood (1:300), and the two are shaken for about 15 minutes; then two drops of ammonium sulphide is added and the whole is examined with a spectroscope. The CO-hemoglobin, which is formed when CO is present in the air, shows two absorption bands, similar to oxyhemoglobin, in the yellow band and on the border of yellow into green, and is not changed by ammonium sulphide. The latter, however, changes the oxyhemoglobin over to reduced hemoglobin, which, in contrast with the two absorption bands produced by the CO-hemoglobin,

shows only one markedly washed-out band in the middle of the oxyhemoglobin band (see Fig. 9). According to this method as low as 2 per cent carbon monoxide can be detected.

If desired, the air may be thoroughly shaken with 10 c.c. of a 20 per cent solution of blood and then mixed by violent shaking with either 5 c.c. of a 20 per cent solution of potassium ferrocyanide and 1 c.c. of 33 per cent acetic acid (in CO-blood a transitory red-brown precipitate appears; in ordinary blood a gray precipitate) or with the three-fold amount of 1 per cent tannin solution. CO-blood also yields in this case a red-brown precipitate and the unchanged blood a gray-brown precipitate. According to this method as low as 1 per cent carbon monoxide can be detected.

Hydrogen sulphide with mercaptan, volatile fatty acids, indol, skatol, etc., arises from putrefactive processes (*sewer gases*). They will be detected by their odor even in very extraordinary dilutions. Even 1/5000 mg. hydrogen sulphide can be recognized by its odor. When 0.5 per cent is present symptoms of poisoning will be observed; above 1 per cent will cause death. The presence of hydrogen sulphide can also be determined chemically with lead paper (which turns black). For more exact methods refer to "Manual on Food Analysis" by Beythien, Hartwich and Klimmer, Vol. 1, page 927. (Leach, "Food Inspection and Analysis," etc.)

Hygienic Importance. These stinking gases seldom occur in the open in such great quantities that the health could thereby be endangered. It is possible in extraordinary instances that where there exists a communication of the stable with a privy, less often with a privy drain, opportunity is afforded for a more marked and harmful pollution of the air with these sewer gases. (See "The Stable.")

Sulphurous acid (and sulphuric acid) is formed primarily through the combustion of sulphur in coal (the average amount of sulphur in coal is 1.7 per cent) and is therefore found to occur to a greater extent in the air of large industrial centers. Furthermore, great quantities of sulphurous acid escape from smelting works (roasting furnaces), alum factories and certain other industrial processes. Direct danger to the health of domestic animals from breathing sulphurous acid is probably just as slight as that from breathing the vapors of arsenious acids, lead and zinc (smelter smoke), which are produced by the smelting of these ores and mixed with the atmosphere of such regions. However, smelter smoke can become injurious indirectly by precipitation on food plants and in that way being fed to the animals. (See "Food Dangers.")

c. Oxidizable Organic Substances (Degree of Air Pollution).

Determination[8]: A moderately large amount of air is drawn through a tube which is not too tightly packed with glass wool. The glass wool is used to hold back the solid organic substances and to some extent the sulphurous acid. The glass wool is placed in a

[8]Krogoe-Petersen. Zur Aetiologie und Pathogenese der Gebaerparese. Inaug.-Diss. Dresden-Leipzig, 1918.

glass stoppered glass cylinder in which there has been previously placed a mixture of 30 parts each of potassium permanganate solution (0.305 gm. to 1 liter) and sulphuric acid (1:3 of water). Ten c.c. of this solution is immediately titrated with ferro-ammonium sulphate solution, and again in 1, 6 and 24 hours. Ten c.c. of ferro-ammonium sulphate solution will exactly decolorize 10 c.c. of permanganate solution. The remainder of the potassium permanganate solution is heated at 50° C. for one hour and then also titrated. The reduction of the permanganate solution, which immediately takes place when the glass wool is added to it, can be attributed to the sulphurous acid. Ordinary dusty air will reduce very little even after one to six hours.

With regard to the determination of stale air with the guaiacum reaction and colloidal osmium, see Weichard and Stötter[4] and Weichardt and Keller[5].

Hygienic Importance. See page 27 under "Gaseous organic matter."

II. Dust.

In every-day life we recognize among the material elements in the air the following groups: Dust, soot, motes in the sunbeams, and microorganisms.

In order to examine the dust of the air microscopically one may either do as Pasteur did, filter the air, through collodion cotton and after dissolving the latter with ether-alcohol prepare the residue for microscopic examination, or place a cover-glass, on which a coating of some sticky substance (glycerin) has been applied, in the path of an air current, which in order to obtain comparative values should be under constant conditions (air velocity, air volume, distance and position of cover-glass to opening through which air enters, the opening being of a certain size). The aeroscope constructed by Pouchel for this purpose consists of a box supplied with an aspirator, the box having a funnel-shaped opening which is directed opposite to a small table on which the cover-glass is laid.

For the quantitative estimation of the total amount of dust in the air a known quantity of air is drawn through a glass tube plugged with cotton, which will register in weight the amount of dust caught in the cotton plug.

The amount of soot in the air is determined by filtering a measured quantity of air through absorbent paper and then making a colorimetric determination[6].

For the quantitative separation and determination of inorganic from organic dust, air is drawn through a glass tube supplied with an asbestos filter; the added weight is determined, the organic constituents heated and burned, and then the loss on ignition is determined, which is considered as the organic dust when making the final estimation.

The dust, whose quantity Tissandier determined as 6.23 mg. in 1 cubic meter of air in the streets of Paris, consists in the open of two-thirds to three-quarters inorganic matter and one-third to one-quarter organic matter. In living rooms and stables there are more organic constituents. Among the latter are plant fibrils, pieces of animal hair, desquamated epithelium, starch grains, horse manure,

[4]Weichardt and Stoetter. Arch. f. Hygiene, 1912, vol 25, p. 265.
[5]Weichardt and Keller. Muench. Med. Wochenschr, 1912, p. 1899.
[6]Ascher. Gesundheit, 1919, vol. 20. Rauch und Staub, 1910, H. 3.

etc. Among the inorganic constituents are quartz splinters, lime and coal particles, minute particles of iron, silicic acid combinations, soot (in 1 cubic meter of Berlin air, 1.01 to 1.4 mg.), sodium chloride crystals, and other similar things. (See Fig. 10.) Among the living things found in the dust pollen grains, which, according to Dunbar, cause hay fever among man and animals (horse) during the blossoming time of grasses. Hay fever manifests itself at the time grass blooms by many horses both in civil and military life becoming sick with the development of a severe catarrh of the upper respiratory tract, head drawn in and a mild fever (39° C.). Recovery takes place in one to three days. There are also found spores of cryptogams, small plant seeds, molds and yeasts, bacteria, minute animals with flagella, infusoria, eggs of worms, etc. The assumption of Zuern and Spinola, that the eggs of lungworms gain entrance to the respiratory tract by means of the dried and powdered slime from swamps and puddles and can cause diseases, has not been proved.

The *coarser dust particles* occur to the extent of 0.2 mg. in 1 cubic meter of street air, but in the country to a considerably less extent (1/100). There is a decided variation in the quantity of dust in accordance with the weather conditions. The principal source of dust is the surface of the earth. The coarse dust which can easily be seen has under ordinary conditions only slight hygienic importance. It is often so coarse that it will only stay afloat in the air a short time and upon being inspired precipitates on the mucous membranes of the upper respiratory tract. In the experiments which Saito conducted not even one-fourth of the dust in the air inspired through the nose reached the lungs. The dust settles principally in the nose and is removed from there largely by sneezing or is swallowed with the secreted mucus. Larger quantities of dust reach the lungs when breathing through the mouth. Only 10 mg. of dust in 1 cubic meter of air is sufficient to cause annoyance. In certain cases, however, where a heavy dust is inhaled for a continued length of time, diseases due to dust inhalation may occur, e.g., inflammation of the lungs, so-called pneumonokoniosis (κόνιος = dust), or catarrh of the respiratory tract, any of which may occur among stonemasons, grinders, millers, etc., also among horses which have to work in limestone quarries or cement works or go on highways which contain lime and are very dusty; also among sheep which graze on dusty meadows or have to go on dusty roads; also where dusty roughage is fed. It is only in exceptional instances, where the dust contains chemical poisons, that poisoning could occur. The case reported by Beckmann[7] was no doubt an exceptional instance of this kind. This was a case of 18 horses of one squadron which suffered from "roaring" as a result of inhaling sand containing lead in a riding school. The sand

[7]Zeitschr. f. Veterinaerk., 1891, 253.

had been obtained from near some old lead works and contained large quantities of lead oxide.

Microörganisms adhere chiefly to the larger particles of dust, which, however, appear as the smallest in the air and are invisible to the unaided eye.

The source of air bacteria is the surface of the earth, the skin and superficial mucous membranes, clothing, etc. No bacteria pass into the air with the evaporation of fluids or moist surfaces. Quietly expired air is free from bacteria. However, when fluids are sprayed,

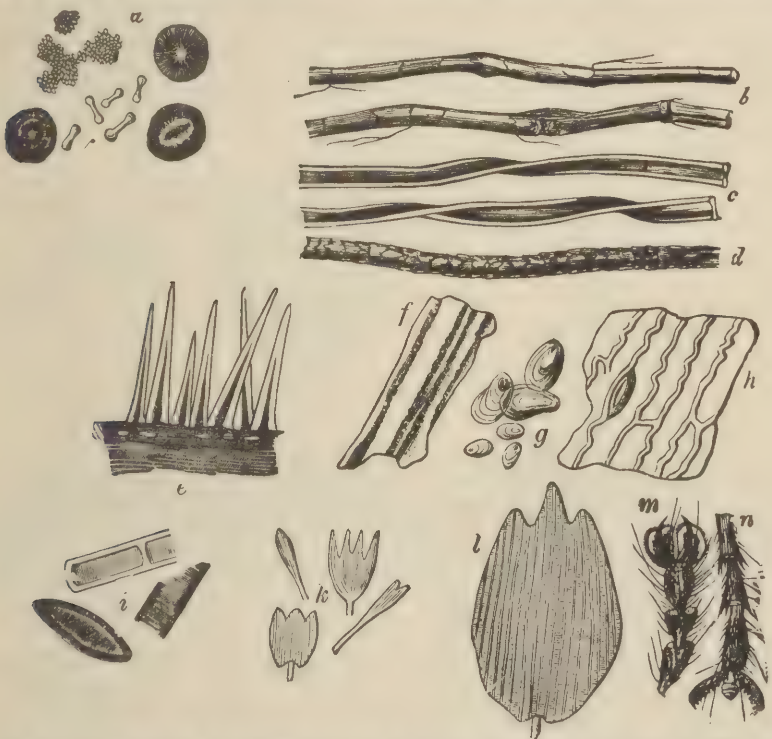

Fig. 10. Dust Constituents. *a*, carbonate of lime in cluster and crystals; *b*, linen thread; *c*, cotton thread; *d*, hair; *e*, plant hair; *f*, similar to *e*, blade of straw with pebble-like structure inside; *g*, starch grains; *h*, superficial membranous plant cell with slit-like opening; *i*, diatom shells; *k* and *l*, scales of butterfly wings; *m*, and *n*, fly and spider legs.

as well as during coughing, sneezing and loud talking, drops of fluid, and with them bacteria, may be mixed with the air. Droplets which have thus become mixed with even very weak air currents (0.1 to 0.2 mm. velocity per second), as they are found to occur in rooms, stables, etc., remain floating in the air, and may be preserved and transported, for some time. When masses of bacteria are dried and adhere to some object, even strong air currents will not detach them and blow them away. They must first be pulverized to dust, as, for instance, by being walked on. With regard to the spores of molds

and fungi, however, the case is different. Even when the fungi grow on a moist surface the dry spores growing on the tips of the seed-bearers which project into the air and which are the smallest and lightest elements in air dust, may, when loosened by slight shaking, even be carried away by very weak air currents.

The number and nature of the germs in the air are principally determined according to the Petri-Ficker method. For other methods see Klimmer's "Handbuch der Nahrungsmittel-untersuchung" or other standard text-books. According to Petri's method two filters are arranged in a glass tube 1.5 cm. wide. These filters consist of coarsely pulverized glass held within fine wire netting and are about 3 cm. high (Fig. 11-a). By means of an air pump or a strong rubber bellows of known volume about 100 liters of air is pumped through the previously sterilized filters. Thereupon the pulverized glass of one filter is mixed with a suitable liquefied culture medium (gelatin, agar, etc.) in Petri dishes, in which the microorganisms which were caught in the filter will multiply and develop colonies. The second filter serves as a control as to whether or not the first filter was impervious to germs. The culture medium mixed with the glass from this filter should show no growth.

In order to prevent germs from slipping through between the filter and the glass tube, Ficker uses tubes provided with bulbs (Fig. 12-a). A small funnel-shaped attachment projecting into the bulb serves as a means of forcing the air to enter the middle of the filter. For further details see Klimmer's work already mentioned.

The number and the nature of the germs in the air vary considerably. On the average, 1 cubic meter of air contains 500 to 1,000 germs, among which are 100 to 200 bacteria, the remainder being molds and fungi. City air contains more germs than country air, and out on the ocean about 750 kilometers (465 miles) from land the air is free from germs. Freudenreich found in 1 cubic meter of air in a Paris street, 4,000 germs, in Berlin only 700, on the Gurten (a mountain near Berne, Switzerland) 8, and on the Eiger (an extremely high glacier in Switzerland) no germs. The air contains less germs during wet weather than during dry weather. No germs are found at altitudes of 1600 meters (practically a mile) in winter or 3,000 to 4,000 meters (1.8 to 2.4 miles) in summer. The bacterial content of the lower limit of the clouds is comparatively high, and many of these bacteria are chromogenic. The air in inhabitated places is usually rich in germs, and this is particularly true in stables. Petri found upwards of 34,000 bacteria and 7,000 spores of fungi in 1 cubic meter of stable air. (See section on "The Stable—Ventilation.")

Most of the germs found in the air are harmless saprophytes, which quickly die in case they are breathed into the lungs. Pathogenic germs have not as yet been found in the free atmosphere, with the exception of pus-producing germs, which are widely distributed in the air. In this connection it should also be mentioned that diseases are only exceptionally transmitted by means of the free atmosphere, since the pathogenic germs which are generally mixed with the air to a limited amount become enormously diluted by means of constant air movements, and through the disinfecting action of the light and dryness their virulence is impaired and destroyed. Probably the

only exceptions are the causative agents of sheep pox, rinderpest and perhaps foot-and-mouth disease. According to the observations of Gilbert, sheep pox is transmitted by means of the free atmosphere for 20 to 25 steps when the air is quiet, and during windy weather, in the general direction of the wind.

On the other hand, infection in closed rooms can occur much more easily and more frequently by means of the air when diseased individuals whose excretions infect the air are present. The infective agents become mixed with the air in droplet form through coughing and snorting, as in pulmonary tuberculosis, contagious pleurapneumonia, swine plague, pulmonary and nasal glanders, equine in-

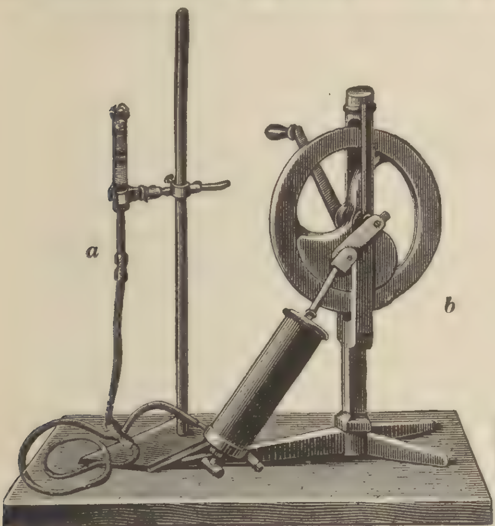

Fig. 11. Apparatus for bacteriological examination of air according to Petri. *a*, Bacterial filter air pump.

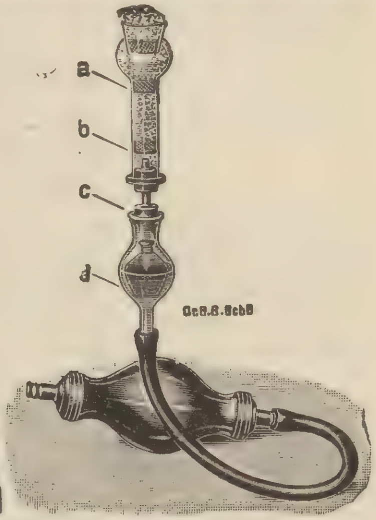

Fig. 12. Bacteriological examination of air according to Ficker. *a*, Bacterial filter.

fluenza, etc. The previously mentioned conditions under which infection is excluded with considerable certainty in the free atmosphere do not apply so much here. Consideration should be given first of all to the situation in the stable where the larger domestic animals, especially cattle, are fastened in close proximity year in and year out and must always breathe within the breathing area of the coughing animals opposite or the ones next to them.

A part of the infectious droplets, as well as the larger masses which are expelled, fall to the floor; they can be licked up or ingested with the feed or water by healthy animals, or they may gradually dry up (as a rule the very moist air of the stable has little tendency to dry), or they may be rubbed to dust and become mixed with the air again as infected dust particles. These dust particles, however, will be infectious again only if the respective infective agents can withstand the drying process, as, for example, in the case of the tubercle

bacillus, the virus of sheep pox, staphylococci, spores of fungi, anthrax spores; less so with the streptococci, etc., and on the contrary not at all with the etiological agent of contagious pleuro-pneumonia. In dust infection the excretion of infective matter is of course not limited to the respiratory tract (sheep pox), as is the case in droplet infection.

In order to avoid droplet infection or dust infection the healthy animals should be separated from the sick and the various parts of the stable disinfected. Even a thorough airing is not sufficient to remove the infective germs from the air.

When new germs do not become mixed with the air a "self-cleansing" of the atmosphere finally results through sedimentation (especially in a closed room), dilution (in the open air), and through destruction from drying and the action of the light.

B. The Physical Conditions of the Atmosphere

I. The Temperature of the Atmosphere

When the sun is at the zenith it radiates in one hour a horizontal square meter of 1,800 calories toward the earth's surface (solar constant). Of this volume of heat about 40 per cent is held back by the atmosphere; of the chemical rays (dark heat) about 60 per cent, and of the light rays about 15 per cent. The drier and more dust-free the air and the smaller the sine of the angle of the incoming rays, just so much more will the air be heated. The light rays which reach the earth's surface are first converted to dark heat rays and warm the lower layers of the air. The heating of the earth is dependent on the position of the sun (geographical latitude); with us it is greatest when the sun is highest, i. e., at noon (June 21). Besides being heated by the sun, the earth radiates heat into the cold (—270° C.) of space adjacent to the earth. As long as the former predominates the temperature rises. This is true in our region until 1:30 p. m. and until past the middle of July. Radiation of the earth's heat is retarded by clouds and by high humidity of the air.

The lowest temperature during the day is observed shortly before sunrise and the highest between 2 and 3 o'clock in the afternoon. The temperature variation between 1 and 2 p. m. seems to be insignificant; up to 1 o'clock and after 5 o'clock a more marked rising and falling respectively occurs (Fig. 18). The greatest temperature variations (15 to 20 degrees, Centigrade scale; 27 to 36 degrees, Fahrenheit scale) are observed on clear summer days as well as during sudden changes of weather and wind in winter and spring. The least variations (even less than 1° C.) are seen on cloudy winter days. The daily variations in winter are on the average 4-5° C. and in the summer 9-10°C. The variations during the year increase with the height of the latitude degree.

For *measuring temperature* the mercury thermometer is commonly used; sometimes the metallic thermometer is employed, and for the extreme cold the alcohol thermometer. In determining the atmospheric temperature the influence of the heat given off by other objects is to be avoided (the sun shining on a wall or on the ground). Quite accurate registrations are also obtained by the use of the centrifugal thermometer (see page 28). The most useful maximum and minimum thermometers

(Six and Bellani) are U-shaped alcohol thermometers in which are inserted a thread of mercury which forces out from each end a steel pin (index) to mark the maximum and minimum temperatures. The registering thermometers are so arranged that the expansion of a metal bow from the heat is carried over by means of a lever to a pen, which writes on a regularly rotating cylinder. The vacuum thermometer (with a blackened mercury container inclosed in an air-free glass case) is used for measuring radiating heat. The difference between is registered temperature and the temperature of the air gives an approximate measure of the radiation intensity.

The average temperature of the day is obtained by adding the hourly temperatures of one day and dividing by 24. Even reading the temperature three times is usually sufficient to obtain a correct daily average if the readings are made at 8 a. m., 2 p. m. and 10 p. m., the last reading doubled, the four added together and the sum divided by 4. Striking an average of the maximum and the minimum temperatures gives only an approximately correct daily average which is usually too high. If the daily averages are added together and divided by the number of days in the month or the year we obtain the monthly or annual average temperatures.

The atmospheric temperature exerts a great influence on the hairiness and thickness of the skin. Comparisons can also be made on weather and pasturage in this regard. The temperature also affects the milk yield of cows which are kept on pasture. When the temperature falls the volume of milk increases, and when the temperature rises the volume is less.

The *hygienic importance* of the variations in temperature is based on the fact that the temperature of the air exerts a great influence on the regulation of heat, as do also (as shown on page 29) humidity, movements of the air, and the natural (hairiness, shedding, layers of fat) and artificial (blanketing) means of heat preservation.

Too high temperatures can lead, as a result of retarding heat loss from the body, to heat stasis (heat-stroke), or, as a result of intensive heat from the sun (insolation), to sunstroke. Insufficient heat or too rapid cooling off can lead to a cold or to freezing.

The harmful effects of sunstroke are due to the intensive heat from the sun and produces in this case irritation of the skin and mostly symptoms of cerebral irritation and even cerebral meningitis. Bones, muscles and fat allow the heat to pass through more readily than the brain, and as a result a more marked accumulation and absorption of heat occurs on the upper surface of the brain. A cranium composed of skin, cranial bone and dura is rayed through by a 65-candle power Nernst lamp in 15 seconds.

Sunstroke has been observed many times in domestic animals, e.g., in horses, cattle and sheep, and very often it is combined with heat-stroke.

Heat-stroke, caused by heat stasis as a result of retarded heat loss, occurs during a bright, sunny day, but more often when the sky is overcast and the air is warm and humid. On the other hand, when the temperature is high but the air dry and protection is afforded against direct insolation and sufficient water is being drunk, heat-stroke as a rule seldom occurs, since heat loss is sufficiently maintained under these conditions. If the body temperature rises to 43 to 45° C. (109 to 113° F.) the animals die under symptoms of exhaus-

tion, cerebral congestion, drowsiness, syncope and tetanic spasms (see page 31).

As a result of the prolonged action of a moderately high temperature, chronic partial heat stasis may occur. In this manner many (nervous) horses withstand very poorly a prolonged heat of 25° C. (77° F.) as a daily average, particularly when the nights do not cool off very much and the air is humid and quite still. In such cases loss of appetite may result.

Indirectly, if sufficient moisture is present, high temperatures promote the multiplication of putrefactive and pathogenic germs (see page 30) as well as molds and fungi which attack fodder, etc. On the other hand, when it is dry the forage plants become scorched and wither and result in considerable dust formation; the drinking water loses to a greater or less degree its cooling and refreshing action and may even dry up so that the animals will suffer the loss of this food, which is particularly necessary at a time of extreme heat.

The resistance of the different kinds of domestic animals to heat varies. Generally the horse withstands heat best, sheep least, and cattle, swine and dogs stand halfway between. Lean animals with delicate skin and thin coat of hair suffer less from the heat than very fat animals. Horses suffering from chronic hydrocephalus (sometimes known as "dummies") show an increase in their depressed condition or have attacks or fits resembling mania.

Prophylaxis consists in providing cool, fresh water, perhaps made somewhat acid with hydrochloric acid or vinegar, yeast water or sour milk; also succulent green feeds, cooling baths, and pouring cool water on the body, shade (green trees and shelter sheds), and avoiding exertion during the hottest time of the day. Very fat animals should be transported at night whenever possible. No objection is to be raised against the straw huts provided in many cities in Germany by the Animal Protective Society for horses as protection against sunstroke during the hot summer.

Freezing of individual parts of the body or of the entire body in our climate does not occur in cases where sufficient food is eaten and plenty of muscular exercise taken. There is no danger to health or life until one of these factors fails, which may occur when a strong, cold wind blows (during sleep, digestive disturbances or being insufficiently fed). A temperature of —30° C. and no wind is withstood better than —10° C. and a strong wind. A high relative humidity acts as a factor to increase the effect of the cold (see page 31).

During freezing we first observe anemia of the skin and cooling of the peripheral parts of the body (ears, tail, ends of the extremities). Local paralysis of vessels follows, with hyperemia and swelling, slowing of the circulation, and even stasis. Finally the peripheral

parts freeze (i.e., death and necrosis of the cellular elements occur). Prolonged contraction of the skin vessels leads to pulmonary and cerebral congestion with their sequelae, pressure and headache, later staggering ("dummy") symptoms, dizziness, syncope, and finally death through paralysis of the central nervous system. Death due to freezing has been observed infrequently among domestic animals, but freezing of individual parts of the body (ears, end of the tail, tips of the feet) occurs otener, especially in pigs. Continued moderate cold is withstood best by sheep and most poorly by horses. If animals are insufficiently fed, continued cold leads to emaciation. Feeding animals only sufficiently to maintain them or to condition them moderately while they are being kept in a cool place for a long period of time is wasting feed.

Limited amounts of cold (such as drafts) can give rise to diseases due to chills, particularly if they strike the body while it is very warm. A decided amount of cold is not necessary to bring this about, but the change from warm to cold must be very sudden. A high humidity (fog) increases the action of cold. This is particularly the case with lambs, in which fog has often resulted in severe muscular rheumatism.

The exact nature of a cold is not yet fully understood. Usually one assumes that the contraction of the skin vessels results in a hyperemia of the internal organs, especially the mucous membranes and particularly those of the respiratory tract. Frequently the hyperemia may occur along with exudation, formation of fibrin coagulum in the lungs, capillary and other small hemorrhages in the lungs, trachea, larynx and pharynx, with a simultaneous decrease and weakening of the phagocytes. Aufrecht attributes the coagulation of the blood (coagulum in the lungs and other organs) to the toxic substance resulting from the destruction of the leucocytes, which in turn was caused by the irritation from the cold; and he attributes the vascular changes following the hemorrhages to the toxic substance in the blood arising as a result of the cooling off. The protective epithelium (e. g., in the lungs) suffers injuries through exudations and hemorrhages. In this way a locus minoris resistentiae (place of lowered resistance) is afforded for the invasion of pathogenic germs. A simultaneous infection is a proved fact in very many diseases due to a chill, e. g., in pulmonary and mammary inflammations, catarrhal conditions of the respiratory tract, etc. In addition there are no doubt true chill diseases in whose development no infectious matter is concerned. In this group would come especially muscular rheumatism, the neuralgias, laminitis, crampy colic, etc. From among the extensive literature on this subject see Kisskalt[8] and Sticker.[9]

Prevention against freezing: Ample food and exercise or blanketing, and if necessary warm quarters. Prevention against chill or catching cold: Hardening or toughening, proper care of the skin; avoid sudden severe changes of temperature, etc.

By hardening is not meant a physical development of the cutaneous muscles so that they will react by contracting to each irritation from cold, as was at one time advocated, but rather that the body should accustom itself to cold. Fuerst found that in both man and animals repeated, short and mild cold and

[8] Kisskalt. Arch. f. Hygiene, 1901, vol. 39, p. 143.
[9] Sticker. Erkaeltungskrankheiten u. Kaelteschaeden, ihre Verhuetung u. Heilung. Julius Springer, Berlin, 1916.

heat irritations produced a thickening of the epidermis (by means of increasing the size of the epithelial cells and forming new ones) up to eight times the normal, by which means the terminal points of the cold nerves (sensory nerves) are more protected and therefore become less exposed to the cold.

II. Atmospheric Pressure.

At sea level the air pressure balances a column of mercury which is on the average 760 mm. high. Since a column of mercury of 1 sq. cm. weighs 1 kg. (2.2046 lbs.), it follows that a column of air of 1 sq. cm. and which is as high as is the atmosphere must also weigh 1 kg. Air pressure therefore amounts to 1 kg. for each square centimeter. Therefore a full-grown cow, whose body surface amounts to 6 square meters, is subjected to air pressure amounting to 60,000 kg. If the air pressure drops 10 mm., it means a decrease of pressure of 816 kg. to 6 square meters of surface. Air pressure is not perceptible, since it comes from all sides and the body is not compressible.

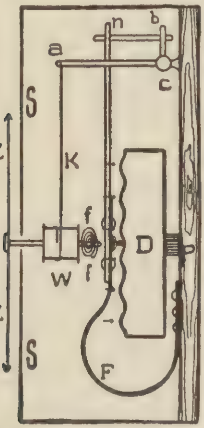

Fig. 13. Aneroid Barometer.

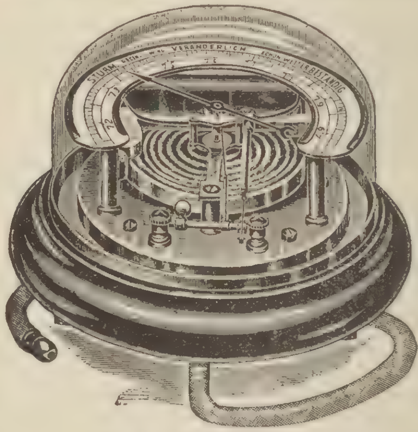
Fig. 14. Aneroid Barometer.

As one passes upward from the level of the sea the air pressure drops, and indeed in the lower strata the mercury drops 1 mm. at an elevation of 11 meters; at an elevation of 1,000 meters it amounts to only 760; at 2,000 meters 570, at 3,000 meters 520 mm. The highest city is Gartok in Tibet; it lies 4,320 meters above sea level. The highest city in Europe is Mont-Louis, France (1,570 meters). If cities having the same atmospheric pressure whereby the heights are reduced to sea level are connected by lines on a map, the lines of equal atmospheric pressure, or isobars, are obtained. For the most part they form closed circles around which the remaining isobars lie concentrically at greater or lesser intervals.

The air pressure in our latitudes is subject to irregular and slight daily fluctuations, which only occasionally reach 20 mm. We subject ourselves to the same fluctuations when we ascend a hill of 220 meters height or if we descend from the same height into a valley. The annual variation amounts to 30 to 50 mm. (corresponding to a difference in height of 330 to 550 meters). The minimum occurs in summer; the maximum in winter.

For *measuring atmospheric pressure* the mercury barometer is used (difference of the height of the mercury in both sides of the barometer), or the aneroid barometer (Figs. 13 and 14). The latter consists of an air-free thin metal box (D) with a corrugated lid which is pressed together either markedly or slightly according to

the existing pressure, and a pointer (Z) or dial which is connected with the lid and which shows the movements of the capsule and indicates the atmospheric pressure on a scale.

Hygienic Importance. The slight differences in pressure which occur on the inhabited surfaces of the earth are of importance mainly so far as they really influence the weather. There is as yet no unity of opinion as to whether the flucuations of air pressure, which occur under ordinary conditions, exert an immediate influence on the health of animals. Such an influence is not very probable when there are but trifling fluctuations. However, there are authors who assume that there is such an influence. Thus Krogoe-Petersen states that parturient paresis in cows occurs only when the barometer is low or falling.[10] According to Andersen, cows which were suffering from parturient paresis, before the introduction of the Schmidt method of injecting the udder, were more easily cured when the air pressure (barometer) was rising than when it was falling. When the weather is hazy and damp (low barometer), different diseases (colic, etc.) should increase. I can not confirm this, however, with regard to colic. Whether the falling barometer is concerned as a cause appears at least questionable. Finally it is to be noted that the air on the ground (regarding its irregular composition, see page 46) rises above the earth's surface when the air pressure is falling and that it can penetrate into stables.

III. Atmospheric Movements.

The atmospheric movements arise through the differences in the pressure of the air, and these in turn are caused by the differences in temperature.

Under atmospheric movements we will consider direction, velocity and force. The following compilation illustrates the relation of atmospheric velocity to force and makes possible a simple, approximate determination of the velocity:

Wind Force		Wind Velocity (Meters per second)	Atmospheric Pressure (Kilograms to 1 square meter)	Action of Wind
Quiet	(0)	0 to 0.5	0 to 0.15	Smoke rises almost perpendicularly.
Weak	(1)	0.5 to 4	0.15 to 1.9	Perceptible breeze; moves a pennant.
Moderate	(2)	4 to 7	1.9 to 6	Moves leaves.
Brisk	(3)	7 to 11	6 to 15.3	Moves tree branches.
Strong	(4)	11 to 17	15.3 to 34.5	Moves strong limbs.
Storm	(5)	17 to 28	34.5 to 95	Sways entire trees.
Hurricane	(6)	Above 28		Destructive action.

For *measuring* the velocity of the wind a dynamic anemometer is used. Robinson's crossed-cup anemometer is the most widely used (Fig. 15). This consists of a

[10]Krogoe-Petersen (Zur Aetiologie und Pathogenese der Gebaerparese, Inaug. Diss., Dresden-Leipzig, 1918) looks upon parturient paresis as a cerebral anemia induced by a hyperemia of the cutaneous vessels (and a transitory hyperemia of the mammary vessels). The cause of the hyperemia is the diminution of the atmospheric pressure on the cutaneous vessels. The diminished pressure within the abdominal cavity as a result of parturition is assumed to act as a factor to increase the effect of the atmospheric pressure.

horizontal, rotary cross whose arms are of equal length and on the ends of which are bowl-shaped cups all facing the same rotary direction. Wind, which strikes the crossed cups, glides from the convex sides of the cups and is caught in the concave sides, where it exerts an increased pressure (over that on the convexities); in this manner the crossed cups are rotated. The axle on which the crossed cups rotate is firmly joined to the cups. Toward the lower end of the axle are threads connecting with a computing mechanism.

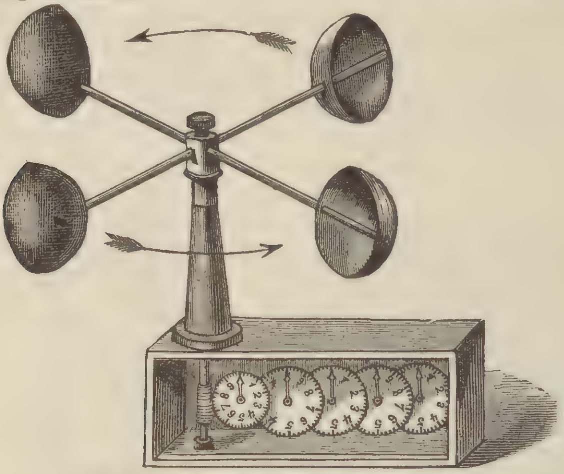

Fig. 15. Robinson's crossed-cup anemometer.

The air pressure can be computed from the rapidity of movement or measured by means of a static anemometer. A static anemometer is usually constructed of a series of fans which cross one another at their centers, the apparatus standing vertically (Fig. 16). A watch spring prevents the axle from revolving completely. A pointer attached to the axle is deflected either strongly or weakly according to the air pressure.

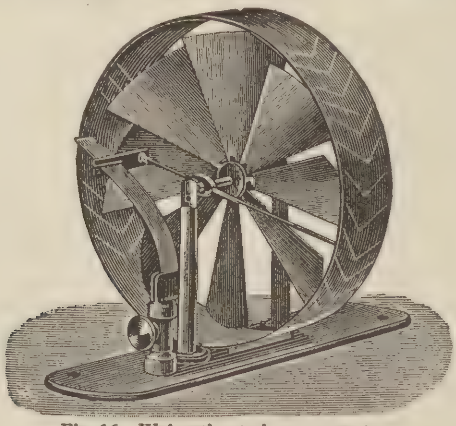

Fig. 16. Wolpert's static anemometer.

The direction and the velocity of the air movements in a closed room can be easily approximated by means of the smoke from a cigar. In order to determine slight air movements in ventilating channels or to determine where the air passes through the walls or floor, the differential manometer and the pneumometer of Krell (micromanometer) and the apparatus of Schip are

used. The manner in which natural ventilation proceeds can also be ascertained according to Pettenkofer's method. This is based on generating a large quantity of carbonic acid gas in the room to be examined as to ventilation; the carbonic acid gas content is determined at once and at regular intervals thereafter. The extent of the ventilation is computed from the decrease in the carbonic acid content according to the following formula of Seidel: $C = 2.303 \times m \times \log \frac{p_1 - a}{p_2 - a}$. In this formula C represents the extent of the ventilation (which is being sought), m the contents of the room or stable in cubic meters, p_1 the CO_2 content (artificially increased) before beginning the experiment p_2 the CO_2 content which has been decreased through ventilation up to the close of the experiment, and a the carbonic acid content of the outside air.

The *Hygienic Importance* of the atmospheric movements rests, on the one hand, on direct, and on the other, indirect influence on the animals.

The direct influence of the wind is first of all on heat loss, since air movements augment the conduction of heat from the body and the heat currents, refreshing one during intense heat and freezing or chilling during intense cold. Furthermore, a strong wind will interfere with breathing when the animal is forced to run fast against the wind. The direction of the wind is of importance in so far as it tends to influence the temperature and humidity. The north and particularly the northwest winds are the coldest, and the west winds on the average the driest, although the dryness is often changed to comparatively high humidity if the dry wind first sweeps over a large body of water. The north and northwest winds often lead to chilling and diseases of the respiratory organs.

Indirectly the atmospheric movements are of hygienic importance, inasmuch as they (by their direction) influence the weather, mix the air and carry away impurities. On the other hand, the wind can whirl up great masses of dust and mix it with the air, after which it settles on plants.

IV. Precipitation

Various precipitations result from condensation of the atmospheric water vapor (see section relating to atmospheric humidity). The quantity of the precipitation is dependent upon the extent of saturation of the air and the intensity of the cooling.

For the determination of the quantity of the precipitation (rain, snow) a so-called rain-gage (ombrometer) is used (Fig. 17). It consists of a collecting vessel whose collecting surface is of a definite size, usually 500 sq. cm. The precipitation is collected in a graduated cylinder whose graduations indicate the quantity of the water in 1/10 mm. which would have collected on the surface of the earth had no drainage, or evaporation taken place. Recently Hellmann's registering rain-gage has come to be used extensively.

The influences of precipitation are numerous. It is of benefit indirectly in cleansing the air and the earth, settling the dust and furthering the growth of plants, and directly by being refreshing during

intense summer heat and ridding the body of dust and insects. Harm can arise through causing diseases due to sudden chilling (as by a cold cloudburst striking overheated animals) and disturbances of nutrition. The latter are observed in sheep after a protracted rain (appearing as chlorosis and hydremia). Furthermore, rain favors the development of parasitic and soil diseases (distomatosis, lung-worm and stomach-worm diseases, anthrax, blackleg, etc). (See page 57.) Feed that has been cut becomes washed out during a prolonged rain and undergoes decomposition more easily. After a prolonged drought a warm rain will cause rapid and luxuriant growth of forage plants, which easily cause tympanitis when eaten green by the animals. Feed that has grown during a prolonged rain con-

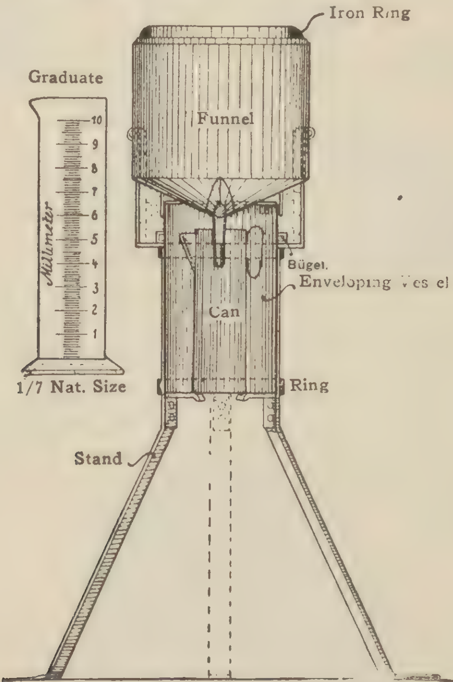

Fig. 17. Gauge for measuring rain.

tains more water and less nutritious substances than other feed. Frost-bitten feed gives rise to catarrh of the stomach, colic, diarrhea and abortion in animals whose period of gestation is drawing to a close. These diseases can be easily avoided by allow the feed first to dry in the stable or by feeding the animals some dry feed before they are turned out to pasture so that they do not eat the frost-bitten grass on an empty stomach. The harmful action can be substantially reduced also by accustoming and hardening the animals to such feed. Animals whose skin is tender and which are allowed to run in the

snow a long time occasionally develop an inflammation under the pastern and in the interdigital space, etc. The level of surface and subterranean water is also influenced by frequent precipitations.

V. Atmospheric Electricity and Light

Very little is understood regarding the action and significance of atmospheric electricity (high uni-polarity, atmospheric ionization, change in the electrical potential fall of the atmosphere). Its hygienic relations have not been definitely determined up to the present time, but have often been assumed.

Electrical discharges (lightning) have less hygienic significance than is generally assumed. Deaths and injuries due to lightning are of rather infrequent occurrence, although this varies according to the climate. Protection by means of lightning conductors (lightning rods) is quite generally known.

Light influences the general condition of animals. The number of erythrocytes increases under the influence of light. More carbonic acid is excreted in the light (irritating action on the protoplasm), and metabolism procedes more rapidly than in the dark. Since there is diminished metabolism in the dark, the animals fatten better under these conditions. Inasmuch as cleanliness largely depends on light, a sufficient entrance of light to the stable is desirable from a hygienic standpoint. We must also consider in this connection that light exerts a tremendous influence on the life of microorganisms. Direct sunlight will destroy pathogenic germs and even their spores in a few hours; diffuse daylight requires 4 to 7 days to destroy them. The streptococcus of mastitis is killed in 5 to 15 hours by direct sunlight and in one-half to 2½ days by diffuse daylight, and blackleg germs in 1½ days by direct sunlight and 4½ days by diffuse sunlight. On the other hand the disinfecting action of light should not be overestimated, since its penetrating action is very slight. In plants the light influences the production of chlorophyll, lignification, etc.

Strong sunshine often produces harmful results. Tender, unpigmented skin which is only slightly covered with hair has been observed to become inflamed (erythema solare, dermatitis gangrenosa solaris). Sometimes sunburn develops in a horse every year, appearing as a superficial dermatitis of the lips and nostrils which sometimes spreads to the mucous membrane of the mouth and nose. The skin becomes hot, painful and swollen and the epidermis is cast off. The exanthema lasts about 10 to 14 days. Sunburn also appears on other tender parts of the skin, especially on the white, unpigmented areas. It has also occurred in cattle (external aspect of teats, that part of the vulva which is not covered by the tail, and on the muzzle). Occasionally actual skin burns develop (necrosis). Sunburn occurs mostly when the animals are in the open, but can occur

when they are in the stable. It is most frequent in the early part of the summer, the animals becoming accustomed to the sun later in the season. (Regarding sunstroke see page 41). Glaring light can cause over-irritation of the optic nerve and may even lead to blindness. Harmful effects of light rays may also occur through the assistance of certain photodynamic substances which apparently possess the quality of fluorescence. In this way buckwheat exanthema (See Klimmer's Scientific Feeding of Animals), which appears only when the sun shines, is traced back to a coloring matter, fluorescent fluorophyll, which can be extracted from the buckwheat, namely, the hulls. Such photodynamic substances which sensitize sun rays are fairly well distributed throughout the vegetable kingdom and can also be looked upon as the cause of so-called "clover disease" which follows the consumption of large amounts of clover (*Trifolium pratense*) and Swedish clover (*Trifolium hybridum*). Alfalfa (*Medicago sativa*), St. John's wort (*Hypericum* varieties), *Medicago denticulatum,* knotgrass (*Polygonum persicaria*), potato plants, lupines, etc., lead to similar disease conditions, in which molds and fungi which attack fodder are probably also concerned.

Eosin, which is used to denaturize winter barley, should also be mentioned here. If eosin is injected subcutaneously into mice and they are at the same time exposed to intense light, necrosis of the ears, falling out of the hair and necrosis of the skin on the head and back result. Similar observations have been made in human beings on which eosin had been used in treating epilepsy. Winter barley which has been denaturized with eosin is as a general thing not harmful to hogs. If, however, the hogs are allowed out in the open where they are exposed to strong sunlight, it is claimed that severe and even fatal diseases can occur.

Hematoporphyrin, a decomposition product of blood pigment, also possesses marked photodynamic properties. According to Schanz, heat-stroke and sunstroke can probably be traced back to such decomposition products of blood pigments.

Light changes the structure of proteins and may also bring about such changes in the blood serum. The solubility of proteins is reduced by light. The action of light is increased by means of the photodynamic substances. On the other hand, however, the organism has at its disposal certain substances which retard the action of the light. The photosensibility of proteins is easily demonstrated experimentally. If a solution of proteins is exposed at 15° C. to the rays of an arc lamp, the proteins, through the action of the light rays of short wave length, are first changed to difficulty soluble proteins (albumins and globulins) and finally to insoluble proteins. The development of senile cataract is, among other things, dependent upon the coagulation of proteins which is induced by light.

The disease symptoms are dermatitis of the ears, eyelids, head and nape of neck with marked itching, cerebral irritation (excitability and later dullness; spasms and later paralysis), and disturbances of the digestive apparatus. Postmortem findings: infiltration and hemorrhages in the subcutis; death and agglutination of leucocytes resulting in capillary thrombi; swelling of the liver and kidneys. It is possible that hemoglobinurea of horses is caused by a hemolysis induced by a sensitization of the red blood corpuscles by bile pigments.

C. Weather and Climate

By *weather* we mean the collective atmospheric conditions of one locality or region at a certain time. The daily weather conditions taken collectively throughout the year or years in one locality constitute the climate of that region.

Weather and climate are determined by several individual factors, namely, atmospheric temperature, humidity, air pressure, atmospheric movements, precipitations, electrical conditions of the air, and light (sunshine).

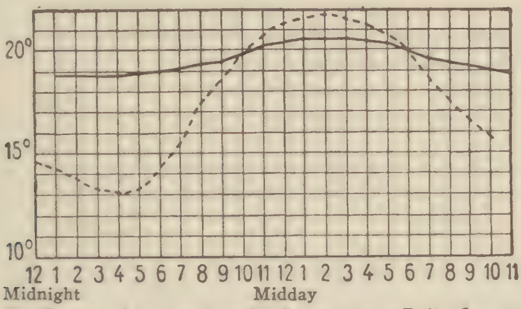

Fig. 18. Course of temperature in the summer. Daily fluctuation.
.... Land climate (Paris).
———— Ocean climate (Atlantic ocean 30° north latitude).

The weather as a whole has a decided influence on health, particularly when many rapid changes occur. If cold, damp weather suddenly follows a warm period, diseases due to cold frequently result (spring and fall). On the other hand, when warm weather appears, intestinal disturbances often occur (in summer). Weather also influences infectious diseases. When the temperature drops malaria decreases. After heavy rainstorms anthrax occurs more frequently. (See page 44, "Atmospheric Pressure.") When weather becomes bad and during intense heat parturient paresis is said to occur more frequently.

From the foregoing it may be concluded that the seasons, which are distinguished by certain weather conditions, have a noticeable influence on morbidity and mortality. During the coldest and rawest first quarter of the year contagious pleuro-pneumonia of cattle, pectoral influenza and periodic ophthalmia of horses as a rule reach their

maximum, whereas in the third quarter they reach their minimum. Chronic hydrocephalus ("dummy") and acute hydrocephalus increase during the hot second and third quarters of the year, and soil diseases (anthrax, blackleg, erysipelas, etc.) occur mostly during the third quarter (compare page 70) as the following compilation shows:

Diseases	Quarters of the Year First	Second	Third	Fourth
Contagious pleuro-pneumonia of cattle: In every 10,000 animals during 1886-1900 there occurred on the average...........	0.175	0.161	0.133	0.148
Pectoral influenza: In the armies of Prussia and Wuerttemberg during 1892 and 1898-1904 there occurred on the average......	741.3	160.4	155.5	719.1
Periodic ophthalmia: Ditto	41.6	34.9	25.4	26.5
Chronic Hydrocephalus ("dummy"): Ditto...	2.6	6.5	6.0	2.75
Acute hydrocephalus: Ditto................	7.1	15.9	22.4	7.4
Anthrax: In every 10,000 cattle during 1886-1900 there occurred on the average........	0.38	0.44	0.45	0.42
Blackleg: Same as preceding except during 1888-1900	0.042	0.08	0.133	0.094
Erysipelas: Cases developing during 1897-1904, average.........................	2,880	12,127	24,554	9,845

The *climate* of a given region is determined by its position (latitude, distance from the ocean and altitude). With reference to latitude, there are the recognized polar climate, temperate zones (where the annual temperature ranges from 0° to 20° C.) and tropical climate. According to the relation to the ocean there is recognized coastal climate or sea climate and land climate. According to the altitude we have mountain climate, highland climate and lowland climate.

The climate on the ocean (compare Fig. 18) is characterized by low, even temperatures in the summer and relatively high temperatures in the winter; slight daily, monthly and annual flucuations (the latter not over 15° C.), as well as by high atmospheric humidity and strong air currents. In contrast to this the climate on the land shows great fluctuations in temperature (hot days and hot summers, cool nights and cold winters; annual fluctuations ranging from 20 to 60° C.), also less atmospheric humidity and fewer air movements.

The climate at higher altitudes is characterized by less atmospheric pressure, less dust, diminshed atmospheric humidity (however, the quantity of rain is often considerable), more intense sunshine, and marked daily fluctuations of temperature (the temperature drops on the average 0.57° C. for every 393.7 feet of increase in altitude). The climate at high altitudes exerts a great influence on the body, especially the blood. The relative content in red blood corpuscles, hemoglobin, iron, oxygen absorption, solid matter and the specific gravity are increased.

When ascending to a higher altitude an increase in the number of red blood corpuscles and the hemoglobin content results within a few hours. whereas a decrease occurs more slowly upon descending

to the lowlands. During this increase no microcytes or nucleated blood corpuscles appear in the blood, nor do shadowy and degenerative forms appear during the decrease. The blood is more concentrated at higher altitudes—more red cells, hemoglobin, iron and protein; therefore it is a relative concentration, not an absolute one. The hemoglobin content appears to be really somewhat more increased only in animals which were raised at higher altitudes. According to Zuntz and his associates, such blood changes as have been described occur in only about 50 per cent of cases. Regarding the influence of high altitude climate on the pulse, blood pressure, body temperature, respiration, etc., see Zuntz's work.[11] With reference to the cause of these occasional blood changes, the lowered atmospheric pressure is to be considered. The climate is furthermore influenced by the nature of the earth's surface (geology, water supply, vegetation and natural formations—woods climate and steppe climate, etc), very close relationship existing between the climate and the earth's surface.

The climate as well as the ground exerts an influence on the animals. Both are very important factors in the origin of breeds and their variations. Many breeds owe their characteristics to the topography of the earth's surface on which they developed. Besides climate and topography, the care and feeding of animals as well as selective breeding exert an influence on the development of breeds.

Living continually in cold and moist climates causes the skin to become thicker and the hair denser, coarser and longer than they would be in warmer and drier climates. The influence of the climate on our domestic animals is in many respects markedly influenced by the manner in which they are cared for and fed. The skin and hair become darker in warm climates as a means of protection against the more intensive light (ultra-violet rays) that is found here. The horny appendages (hoof, horns) develop more in warm, dry climates than in cold and moist ones, whereas the bones develop more in the latter as far as circumference is concerned. The different breeds and their variations become larger in temperate climates than in the hot or cold climates. High altitude climates promote the development of the respiratory apparatus (large, well-developed thorax). The influence of climate on the udder and milk yield is well known. This, however, is an indirect influence, since it is the quality of the forage that is the influential factor. The temperament is livelier in dry and warm climates, and in moist climates the ability to fatten is greater and maturity is reached earlier.

When attempting to characterize the different climates today so that the characterization will be useful for hygienic purposes very great obstacles are met, which are of greater importance here than

[11]Zuntz, Loewy, Mueller and Caspari. Hoehenklima und Bergwanderungen, 1906, p. 191.

when applying the value of the meteorological influences. Generally speaking, it may be said that the morbidity and mortality tend to increase as the variations of the different atmospheric conditions increase, particularly the atmospheric temperature.

In cold climates diseases of the respiratory organs predominate and in hot climates diseases of the digestive organs and the blood (piroplasmoses, trypanosomiases). The efficiency of the animals is also affected by the climate; in the tropics it is less than in the temperate zones. English Thoroughbred horses do not reproduce as well on the Continent (France) as they do in England (Gayot). Animals imported from other climates fall prey to infectious diseases more easily than native animals.

It is a known fact that the climate also exerts a marked influence on the vegetation. In the neighborhood of the sea as well as on salty earth in general there is found a particular salt flora; e.g., *Glaux maritima, Triglochin maritumum, Salsola kali, Hordeum maritimum, Juncus maritimus, Scripus maritimus,* etc. Moist regions influenced by the sea climate often furnish excellent pasturage.

The process of becoming accustomed to a climate is called *acclimation.* Acclimation is more easily accomplished where there are only slight differences in climate and when the change is made from a warmer to a colder region than it is from a colder to a warmer. Acclimation to tropical climate is particularly difficult. Even in cases where the individual is able to accustom itself to the changed conditions existing in the tropics, it is stated that the ability to reproduce is often lost, even in the first generation. This, however, is strongly disputed by other authors, who base their statements on personal observations. The highest mountain regions are not favorable to horses, and swine are not able to thrive in the extreme north (Dammann). In acclimation one has to deal with becoming accustomed to changed climatic factors (temperature, humidity, atmospheric movements and pressure, etc.), and above all to the different method of caring for and feeding animals. The process of becoming accustomed to the new conditions is observed to great extent by the changed service the animal renders (milk yield, fertility, ability to fatten, etc.) and the morphological changes (form, size, weight, skin, hair, horn, etc.).

As a general thing one avoids transferring animals from one region to another where the differences in climate are extreme, since experience has taught that the usefulness of the animals diminishes and every following generation degenerates more and more. Furthermore, animals are the product of the earth on which they live. The breeds and their variations which can adapt themselves most readily to changed living conditions without markedly changing their usual customs of living and without change of their bodily or

physiological useful services (the "ecological factors") are naturally most useful.

Raw, cold, windy, high regions which supply little feed do not constitute a promising breeding place for the heavy, cold-blooded horse. Typical continental climates supplying a moderate amount of feed are not suitable for the Shire. The high mountains are just as little suited to cattle coming from marshy regions; the scanty living conditions on continental mountains for Belgian horses and well-bred Down sheep; and primitive feeding and care for purebred swine, etc.

As long as animals have not become acclimated they are more disposed to become sick. The dangers to the health of the animals occur mostly in cases where they have been previously stabled, when teeth and hair are shed, etc., conditions which are always more likely to cause sickness among animals. Therefore, during the period of acclimation the animals should be particularly well cared for.

Section II

The Soil

Even in ancient times Hippocrates, Herodotus, Galen and others assumed that a relationship existed between the nature of the soil and certain diseases, an assumption which has remained popular even to this day and which was not explained upon scientific grounds until a few decades ago as a result of the experimental researches of Pettenkofer and his pupils. Today we not only recognize the relationship between the soil and the so-called soil diseases, but we also know that the nature of the superficial surface of the earth is an important factor in the climate; that it markedly influences in several different ways the well water and spring water and therefore must be seriously taken into consideration in arranging for a water supply and in selecting the location of stables, homes, etc.

The most superficial layers of the earth are of chief hygienic importance, particularly as regards the pollution of the soil and the varying behavior of the soil toward water, the atmosphere and temperature. The geological formations, on which formerly too much emphasis was erroneously placed, are of only slight importance from a hygienic standpoint. Certain physical properties of the soil are of much more importance in this respect than the character of the soil, since a certain kind of soil can vary a great deal even in small, restricted areas, and one and the same variety of soil can possess several features of different hygienic importance. Thus a granite region will lose all of its hygienic peculiarities when crevices are scattered through it which are filled with porous débris or weather-worn material or when the granite is covered with porous layers.

A. Physical and Chemical Properties of the Soil

I. Structure of the Soil

Important factors in the mechanical structure of the soil are the size of the particles and the number and size of the pores or spaces between particles. The surface action of the soil is dependent on these factors.

Whenever the ground does not consist of solid masses of stone, the following differentiation is made according to the size of the particles or fragments composing it:

		Diameter (in millimeters)
1.	Coarse gravel	Above 7
2.	Medium gravel	4 to 7
3.	Fine gravel	2 to 4
4.	Coarse sand	1 to 2
5.	Medium sand	0.3 to 1
6.	Fine Sand	Below 0.3
7.	Clay or loam or humus are those which can be washed away.	

Clay consists of the finest particles of aluminum silicate. If it contains fine sand and small quantities of iron, it is called loam. Humus is sand or loam in which are found considerable quantities of organic (i. e., vegetable) remains. Particles or fragments of different sizes are very frequently found mixed in the earth.

Between the individual particles or fragments are small gaps or spaces, the *pores*. The ratio between the pores and the particles is referred to as the *pore volume*. This is determined by allowing water to seep into a definite amount of earth from below until the earth is filled, the quantity of water necessary to accomplish this corresponding to the pore volume. The latter principally depends upon whether the particles are of similar size or of varying size. When the particles are of the same size the pore volume generally amounts to about 38 per cent, regardless of whether it is coarse gravel, medium sand or loam. If, however, different sized particles of this sort are mixed so that the finer particles fill in the pores between the coarser particles, then the pore volume is naturally substantially reduced (up to 15-10 per cent) and the earth assumes an extraordinary specific gravity.

The size of the pores is directly dependent upon the size of the particles, and the permeability of the earth to water and air is dependent upon the size of the pores. The permeability of the earth rapidly decreases as the pores decrease in size. If we arbitrarily place the permeability of gravel at 100, the permeability of medium sand would be 62, fine sand 46 and loam 0.5. The permeability of the earth to air is also substantially influenced by the humidity of the earth. The moisture is retained in the finer pores when they are filled approximately one-half with water, and the finest particles (clay) become swollen. When ice forms the permeability practically becomes nil.

The size of the pores also determines the ability of the earth to hold water, the "water-absorbing power," and its ability to take up water by capillary attraction (minimum water capacity). Both stand in inverse ratio to the size of the pores. For example, gravel (5 mm. diameter) is only able to hold water to about 12 per cent of its pore volume, whereas mediums and (under 0.5 mm.) holds about 84 per cent. The ability of medium sand to take up water by capillary attraction is only 25 cm., loam 50 cm., clay 1.5 m., and turf and marshy land 5 to 6 m. The cause of the ability to hold water and the capillary attraction is the surface action (attracting action) of the earth. This is true not only as regards water but also vapors and gases (dry earth having fine pores) as well as dissolved substances. Frequently chemical changes occur in the latter instance in which certain double silicates of the earth are concerned. The union of the phosphoric acid, lime and ammonia is accomplished in this manner, conditions which are very important from an agricultural standpoint. In the absorption of albumens, toxins, dyestuffs, etc., we have to deal with typical surface action. A more marked surface attraction, however, occurs only when the pores are very small (humus, loam, finest sand, charcoal, platinum sponge, clay filter). The absorption action is of course limited; when the earth is oversaturated it is incomplete.

II. The Ground Temperature

The temperature of the superficial layers of the earth is influenced by several factors. It can be increased several degrees through very marked putrefactive and oxidation processes. The principal source of ground heat, however, is the radiation from the sun. The darker, more coarse grained and drier the

soil, the more the sun will heat it. The temperature of dark, dry earth will in some localities often rise beyond 50° C. (122° F.) at noon during summer. Radiation of heat from the earth is promoted by the same soil conditions as is the absorption of heat. The specific temperature of dry earth amounts to only one-third that of water. Consequently dry earth is more easily warmed and can actually be considered as warmer, entirely aside from the fact that heat is withdrawn from moist earth by vaporization of the water. The surface of the earth cools considerably during the night as a result of its slight heat capacity, extensive surface, etc. Lying on the ground in the evening or at night can easily lead to a cold. The daily variation of the temperature of the upper layers of the earth often greatly exceeds that of the atmosphere[1].

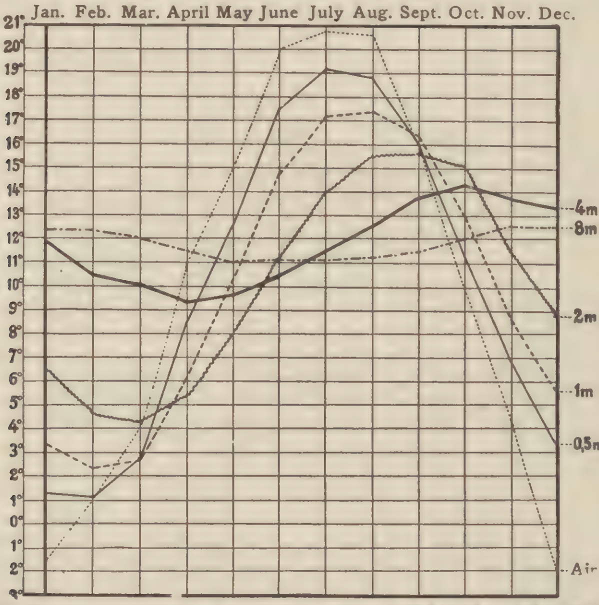

Fig. 19. Temperature of the air and ground or soil 0.5, 1, 2 and 8 meters deep.

The ability of the earth to conduct heat is very limited. In one month the heat will penetrate about 1.5 meters (almost 5 feet). Moist and likewise compact earth is more difficult to heat, but it conducts heat better than dry and weathered earth. As a result of the limited ability of the earth to conduct heat, the temperature variations appear later, according to the depth (for each meter approximately 3 weeks) (Fig. 19) and then disappear. In this manner the daily fluctuations even disappear at 0.5 to 1 meter and the annual fluctuations at a depth of 16 to 33 meters. Here the earth temperature corresponds with the average annual temperature of the air. At greater depths the earth's temperature increases approximately one degree for each 35 meters.

Hygienic Importance: The earth temperature influences the local climatic conditions and the growth of bacteria. Even at a depth of about 1 meter the prolonged higher temperature necessary for a more prolific growth of pathogenic bacteria is no longer obtained

[1]During a day's temperature fluctuation of 12° C. (22° F.) the temperature variation of
the earth's upper layer (sandy loam) was......................27° C. (49° F.)
the earth at a depth of 5 cm. (practically 2 inches)............10° C. (18° F.)
the earth at a depth of 10 cm............................ 8° C. (14° F.)
the earth at a depth of 20 cm............................ 3° C. (5° F.)
the earth at a depth of 40 cm............................0.5° C. (1° F.)

(Fig. 19). On the contrary, the temperature during hot summer days can increase in the uppermost layers of the earth to such an extent that causative agents of disease can thereby be weakened and even destroyed. Reference has already been made to the manner in which diseases due to chilling can be induced.

III. Air and Humidity in the Soil

The pores of the earth contain partly air and partly water, the first being a continuation of the atmosphere. As a result of bacterial activity and the high humidity of the earth's layers, the air in the soil becomes altered, and as a result of the slight velocity (3 cm. in 1 second) of the air movements in the soil, this being caused by the air pressure fluctuations, violent blasts of wind on the surface of the earth and the more marked precipitations and temperature differences, the chemical composition of the air in the soil varies from the atmosphere in the open as follows: Air in the soil is saturated with water vapor, richer in carbonic acid (0.2 to 14 per cent; average 2 to 3 per cent) and correspondingly poorer in oxygen. It also contains traces of ammonia and other decomposition gases, but never microörganisms; small forms of life can be mixed only with the open atmosphere.

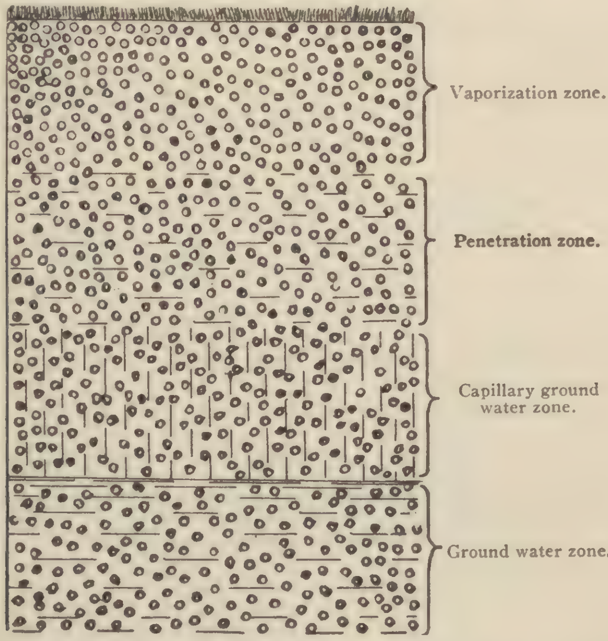

Fig. 20.

Hygienic Importance: The fact that air in the soil is free of germs excludes its possibility of being infectious. Consequently, at the most, only toxic or foul-smelling gaseous constituents can reach the atmosphere or stable air from the air in the soil. However, the slight velocity of the air in the soil and the insignificant amount in which such gases occur there makes them, generally speaking, incapable of doing injury to health. Furthermore, the entrance of air

through the soil can be quite easily prevented by covering the stable and cellar floors with an impervious layer and by cementing the streets.

However, injuries are to be feared when illuminating gas becomes mixed with the air in the earth because of defective gas pipes. The gas, which tends to lose its specific odor as it passes through the soil, can penetrate cellars and ground floors of adjacent houses and stables, and where the upper surface of the earth is impervious (frozen ground, etc.) even several cubic yards of the gas can collect and cause carbon monoxide poisoning.

The *moisture* of the upper layers of the earth as a rule comes from the *atmospheric* precipitation. The rain water partly seeps into the ground, part of it drains off and part evaporates again. The amount of water which seeps into the ground is dependent upon the nature and topography of the earth, the vegetation, the quantity of water existing in the pores, the nature of the rain and the water evaporation. When the rain is moderate and the level of the ground water is very low, the water seeps into the depths very quickly when the earth is very porous, only very little water remaining in the upper layers. On the other hand, the water is held in the upper layers of the earth, when the pores are fine, by the "water-absorbing power" of the earth (see page 57), as a result of which the deeper layers of earth may remain dry.

The water which has seeped into the upper layers of the earth is again given up to the atmosphere by vaporization ("vaporization zone") (Fig. 20). Air-dried earth as a rule still contains some water which is not driven off until the earth is heated to 100° C. (212° F.). Earth rich in organic residues is more hygroscopic than others. Hygroscopically bound water can not be used for sustaining plants.

Below the vaporization zone lies the "penetration zone." The air no longer exerts a drying action on this zone; this layer contains as much water as it is able to absorb. The finer pores are filled with water, the coarser ones with air. The water-absorbing power of soil having fine pores is very considerable. One cubic meter (about 1 cubic yard) of earth is able to hold perhaps 150 to 350 liters (approximately quarts) of water; therefore the precipitations of an entire year may be taken up by a layer of earth 1 to 2 yards thick. The water remains in the penetration zone until it is forced downward by water draining through from above.

Water which has reached a considerable depth is finally prevented from flowing deeper by impervious layers, rocks, or layers of clay or loam. The water spreads out and collects over these impervious layers and entirely fills all pores. These subterranean collections of water are called "ground water," and the particular layer of earth concerned is called the "ground-water zone." At times several separated layers of impervious matter occur, with the ground water arranged in strata, one layer on the other. The time required for a day's precipitation to appear as ground water is dependent on the size of the pores and the thickness of the different layers. In earth having very fine pores and which is not intersected with canals or crevices it may require years before the ground water is reached. Between the penetration zone and the ground water is found the "zone of capillary ground water."

The surface of the ground water is not determined by the shape of the earth's surface but by the configuration of the impervious layer with which it is more or less parallel. Its level is influenced by inflow and off-flow of water. A lateral inflow is possible when the ground-water surface is more markedly inclined and the earth is sufficiently pervious. The velocity of the current in the earth's pores is always very slight, on the average amounting to 25 (10-200) cm. per hour. The lateral off-flow of ground water (drainage water) often has a long way to travel before it reaches certain deeper regions, and, because of the low velocity of the current, is considerably delayed. The variation of the ground water is then no longer influenced by precipitation. According to

Fodor, the highest level of the ground water in Budapest is reached with but the smallest amount of rain, the reverse of this also being the case. The impervious layer on which the ground water lies is often inclined toward the rivers; the ground water usually lies deeper than the river bed. In spite of this the river water does not as a rule flow over to the ground water, because loamy or clay deposits which form on the river bed make it water-tight. It can be proved by chemical analysis of the river and ground water that, even where great differences prevail between the levels, no outflow of water from the river into the ground water occurs. The level of ground water is determined in shafts, which are driven down until they reach the water, the measuring being done with poles or tape measures, cup devices or floaters.

Hygienic Importance: A low level of ground water may seriously interfere with the water supply, whereas a high ground-water level may cause the foundations and walls of buildings to become soaked

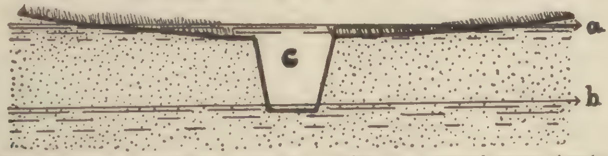

Fig. 21. Lowering of ground water by means of a ditch; *a*, ground water level before digging ditch; *b*, ground water level after digging ditch; *c*, drainage ditch.

through. In case ground water remains for a continued length of time near the surface of the earth, the land becomes swampy, as a result of which certain soil diseases develop and spread more readily;

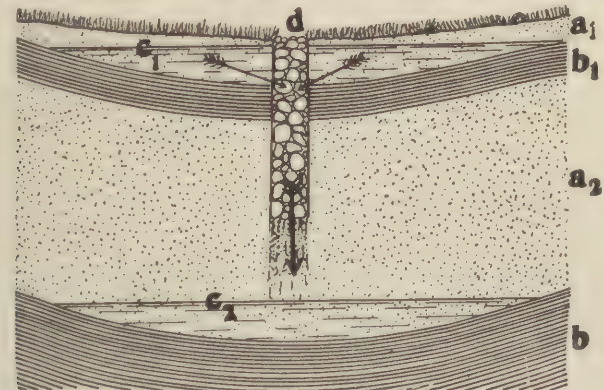

Fig. 22. Draining well (*d*) filled with stones. *a*, surface previous layer; *b*, surface impervious layer; a_2, deep pervious layer; b_2, deep impervious layer; *c*, surface ground water; c_2, ground water draining into the depths.

plant life is deleteriously influenced; grazing animals develop diseases of the feet, sheep showing a purulent dermatitis of the interdigital spaces (foot-rot), horses' hoofs become softened and brittle, with separation of the wall, etc.

The disadvantages of a too high ground-water level can be overcome by ditching and drainage.

Drainage, which is done to lower the ground-water level, is accomplished by the digging of ditches or canals (Fig. 21), or more par-

ticularly by laying drain tile pipes 1.5 to 4 inches in diameter. In cultivated fields the drain pipes should be buried about four feet, in meadows about three feet, in such a manner that the drainage is accomplished through a gradual fall toward the outlet. The fields that are to be drained are provided with a network of such drain tile. The lines of tile should be 10 to 20 yards apart. In case there is a superficial thin, impervious layer, on which surface water stands, above a thicker, pervious one (sand, gravel) which can still take up water, the superficial ground water can be drained into the deeper regions by means of a draining well (Fig. 22). This is accomplished by sinking a shaft into the lower pervious layer and then filling it with pieces of stone, brick or tile, between which the water from above the impervious layer can drain into the depths.

IV. The Solid Constituents of the Soil; Fertilizing.

The principal solid contituents of the soil are carbonates and silicates of aluminum, calcium, magnesium, sodium and potassium, which occur in insoluble or only slightly soluble form. They are therefore more or less unimportant for the biological processes taking place in the soil. Besides these mineral constituents there occur chiefly in the upper layers of the earth admixtures of organic and inorganic substances which are considered as waste materials or impurities. They originate in part from plants (fallen blossoms, leaves, fruits, broken stems, dead roots), in part from the animal kingdom (excreta and carcasses) and in part from waste materials from homes and industries.

The plant and animal waste materials are changed to a fibrous, soft condition by the action of bacteria, some of which ferment pectin. This material is then called *humus.* The soil is classified according to its humus content as follows:

Humus-free earth, humus content............	0 per cent
Humus-poor earth, humus content...........	2 per cent
Humus-containing earth, humus content......	3-4 per cent
Humus-rich earth, humus content...........	5-10-15 per cent
Humus earth, humus content................	Over 20 per cent

Waste materials are sometimes purposely added to cultivated land for fertilization, and sometimes they occur in the land unintentionally. Occasionally, though not desired, they penetrate from manure or dung heaps and ditches into the surrounding soil for as much as 10 yards and down into the ground water. Chemically these waste materials consist chiefly of organic substances, the various putrefactive products of proteins (amino acids, indol, skatol, ptomaines, fatty acids), fats (fatty acids) and carbohydrates (humus substances). There also occur in the animal excreta principally ammonia derivatives (urea, hippuric acid, amino acids, etc.), also chlorids and phosphates. The waste materials are caught in the fine-pored earth and the organic parts broken down by microbial activity, or "mineralized" ("self-purification of the earth"), so that only the inorganic substances remain. When sufficient air is available oxidation processes take place, which are practically odorless, whereby the carbon of the organic combinations is changed to carbonic acid, oxygen to water and nitrogen to nitrous acid and finally nitric acid. When only a limited amount of air is present, or when air is excluded, reduction processes become prominent and ammonia and foul-smelling gases develop. Heat as a rule augments decomposition processes and increases the carbonic acid content of the earth.

The mineralization of organic substances occurs chiefly in the upper layers of the soil where there are great numbers of bacteria. If the organic substances can not be overcome by the microbial life, and if the soil can not unite

sufficiently with the existing great pollution, this organic matter gradually seeps and penetrates to greater depths. Such soil is considered supersaturated.

Carbonic acid produced by the destruction of organic substances partly escapes and is partly absorbed by the water in the soil. This freshens the water and makes it more palatable and gives it greater ability to dissolve salts which otherwise are more or less insoluble (especially carbonates).

Waste materials are of the greatest importance to the growth of plants. They represent an important source of nutrition to them (salts, nitrogenous substances), and for that reason they are purposely used in the form of manure on cultivated land and are used also in artificial fertilizer. Organic substances do not serve directly as food for plants, but they do indirectly in that they are sources of nutrition for certain nitrogen-fixing bacteria, or ammonia or nitrates and other mineral constituents are liberated through their decomposition, which in turn can be taken up by the plants.

Fig. 23. Favorable influence of nodular bacteria on the ground of yellow lupine (1 and 2) and Serradella (3 and 4). I and 3 are inoculated; 2 and 4 not inoculated.

The chemical composition of the earth exerts a great influence on the physical growth of animals through the water and feed. Consequently, on soils rich in lime the larger breeds and varieties are found, and in localities which are poor in lime the smaller ones are found.

The intentional spreading of waste materials on cultivated land is called *fertilizing.* Primarily it aids in promoting plant growth. Its success is indicated by the growth of the plants. If the results are good, the fertilizer has fully replaced the necessary elements for growth, if the results are poor, the fertilizer lacked certain necessary elements. Very often only certain elements

need be considered, which, when they are added to the soil, will cause the plants to grow luxuriantly. Determining such a deficiency and the proper remedy therefor are problems for the agricultural chemist. Stable manure has proved itself to be the best general fertilizer, but it does not suffice alone, since nutritive substances are lost through the sale of grain and animals. Substitutes are therefore necessary.

Furthermore, in fertilizing, the reaction of the soil is to be considered. An excess of either acid or alkali is harmfud to plant life. Usually a certain balance must exist.

Frequently fertilizers undergo changes in the soil and influence its reaction. In closely related fertilizers this can occur quite differently, as, for example, with Chile saltpeter and ammonium sulphate. Both are specific nitrogen fertilizers and can in this sense supplant each other. Even though both are chemically neutral salts, they exert an absolutely opposite action on the reaction of the soil. The plants take up the nitrogenous part and leave in the soil in some instances an alkali remainder and in others an acid remainder which under certain conditions may affect the soil adversely.

Fertilizers may be classified as alkaline or acid as follows:

1. Alkaline: Lime, wood ashes, Thomas (basic) phosphate, "lime nitrogen," marl, bone meal, Chile saltpeter, calcium nitrate (from Norway).

2. Acid: Superphosphate, ammonium superphosphate, potassium superphosphate, ammonium sulphate, potassium salts.

By means of rational fertilization a larger yield as well as more nutritious food is obtained. Thus fertilizers rich in nitrogen generally produce feeds richer in proteins. Only the legumes, alders and a few relatively unimportant varieties of plants are exceptions in this respect. They thrive independently of the nitrogen in manure, etc., because of the action of certain bacteria which occur in the nodules of the roots and which assimilate the atmospheric nitrogen and convey it to their host plants. The favorable influence of the nodule bacteria on the growth of various legumes in soil poor in nitrogen is shown in Fig. 23. Similar symbiotic processes are not observed in other plants such as the different grasses. However, free nitrogen-gathering bacteria occur in the soil. Recently Hiltner recommended appropriate cultures for turnips and sugar beets. Hiltner also had good results with barley. In contrast to this, the "U cultures" and "nitrogen compost" of the agricultural works of Kuehn have not proved successful, according to the reports of Pfeiffer.

Fertilization also exerts on the flora an influence which is not to be underestimated. Thus, by moderate fertilization the dry, tough, bristle-like mat-grass (*Nardus stricta*) which is so widespread on the hill meadows can be killed out, allowing the development of better plants which prefer fertilizers. Nitrogen fertilization promotes the growth of grass; potassium-phosphate fertilization without the addition of nitrogen promotes the growth of papilionaceous flowers (bean family).

The principal manures on the farm (stable manure and liquid manure) are not satisfactory as continuous fertilizers, since the salts and nitrogen of the earth, which are used by the growing crops, are only partly replaced to the soil through the feeding animals. As a substitute, lime (5.5 lbs. for about 11 sq. yds.) is scattered on heavy soil every 3 to 6 years and on lighter soil every 6 to 9 years, or gypsum on clover plants and other legumes (about ½ lb. on every 11 sq. yds.); superphosphate or Thomas meal (ground basic slag) every 6 to 9 years, perhaps sulphate of potash as well as nitrogen in the form of Chile saltpeter, crude calcium cyanamide ("lime nitrogen") or ammonium sulphate. The latter, however, should not be used for leguminous plants. (See discussion of nodule bacteria, above.) The nature of the fertilization is to be varied according to the natural condition of the soil.

It is important to consider the health of the animals when fertilizing land. In the event that the soil is deficient in lime or phosphoric acid, the forage plants grown thereon are likewise deficient and do not supply in sufficiently large quantities the very important salts for the growth of bone in the animals, and in this manner cause the

development of brittleness of the bones and rachitis (halisteresis ossium). Insufficient phosphate of lime is then assimilated by the plants, particularly during dry years because the solvent is lacking. It is a common observation to see these bone diseases appear, particularly during the dry years, in epizoötic form, ever occurring in localities where they are ordinarily unknown. This evil can be prevented by fertilizing liberally with lime and phosphoric acid (Thomas meal, superphosphate).[1] Stable manure and liquid excreta when used as fertilizers do not tend as a rule to prevent or overcome an impoverished condition of the soil—one lacking in phosphates. Rachitis is combated by giving lime salts (calcium chlorid, etc.) and phosphates (natrium phosphoricum) in a form in which they are easily resorbed, dispensing them for internal medication. Inasmuch as sour grasses, deficient in lime, should in all probability also be taken into consideration in the development of bone brittleness, it is well to try to crowd out the sour grasses with more desirable flora by draining the swampy meadows.

If there is a general deficiency of salts in the feed, "licking disease," "wool eating" and in mountainous ore regions a condition called "stable deficiency" develop. By means of abundant fertilization (particularly stable manure, kainite, etc.) and dosing with salt (molasses) in the feed, even this disease can be prevented or cured.

Harm can also be done through fertilization. Too intensive fertilization with saltpeter will increase the saltpeter content, particularly in turnips, which ordinarily contain much potassium nitrate, increasing it from 0.7-1 per cent to 1.3-3.1 per cent of the dry substance. If such turnips are then fed in large quantities (50 lbs.) considerable quantities of saltpeter (about 80 grams) are taken up, which may lead to gastro-enteritis (diarrhea), nephritis and even heart lesions.

If certain fertilizers (particularly Chile saltpeter and gypsum) are scattered on fully developed forage plants and fed to any extent, it has often been observed that serious injury to health and even death may occur. These dangers can be avoided if the fertilizers are scattered as a very fine powder and the rain allowed to wash this off the forage plants before harvesting them. Kainite fertilizer, according to Feser and Gmeiner, and superphosphate and Thomas meal, according to Schneider and Stroh, are entirely harmless. On the other hand, kainite and Thomas meal have been observed to be harmful in certain instances.

In conclusion it is well to mention that no inorganic poisons (particularly lead) should be brought on the fields and meadows, as has

[1] Relative to a simultaneous fertilization with lime and phosphoric acid, Prianischnikow-Moskau (Chemiker-Zeitung 1906, vol. 30, 438) demonstrated that in fertilization with Thomas slag as well as with postassium phosphate (KH_2PO_4) large quantities of carbonate of lime can be introduced without lessening the action of the phosphates. On the other hand, increasing quantities of calcium carbonate decrease the results of the fertilization with bone meal and phosphorite. Ammonium salts (ammonium sulphate, $[NH_4]_2SO_4$, which represents a typical physiologic acid salt; also ammonium nitrate, NH_4NO_3, exert a marked dissolving action on crude phosphate in sand cultures and in that way favor the results of phosphate fertilization.

often occurred when waste or by-products containing lead from various industries (dye and linoleum factories) have reached the fields and resulted in serious and even fatal cases of poisoning.

B. Microörganisms in the Soil and Soil Diseases

The superficial layers of the earth harbor many bacteria; indeed, the number increases with the amount of organic matter. Humus soil in the superficial layer contains several millions of bacteria per cubic centimeter; forest soil (diluvial formation), one-half to 2 millions; field soil (potato, clover and grain fields), one-half to 10 millions; untilled land and meadow soil grown over by grass, one-half to 5 millions.

The most superficial layer of earth harbors somewhat fewer microörganisms when the plant growth is deficient, because the inhibiting and killing actions of the various atmospheric processes (sunlight, drying, etc.) are then more noticeable. Beneath this thin layer, for a depth of about 4 inches, the number of germs is greatest, and then it rapidly decreases. At a depth of 3 to 6 yards the earth is usually free from germs. However, Kabrhel's comprehensive researches in this connection show that the germs, which progressively decrease in number from the surface to a depth of 1.3 to 1.5 meters, occasionally and indeed only in exceptionally clean ground not only do not decrease at greater depths ordinarily considered germ free, but may increase to the same extent that they are found near the surface. Such marked irregularities and extremes in germ content of the deeper layers of the earth are observed in forest soil. If the soil is under cultivation, then the germ content also frequently increases at greater depths, but such noticeable variations in numbers are not observed. Those parts of the earth through which the ground water passes (2 to 4.5 meters deep—about 6.5 to 14.5 feet) are also quite rich in bacterial vegetation, in spite of the fact that they may lie in a location considered ideally clean.

The germ content of soil is determined in the following manner: An accurately measured amount of soil, .01 to 1 c.c., is mixed in 10 to 100 c.c. nutrient gelatin or sterile water for the purpose of diluting it. Of this several loopfuls to 0.1 c.c. are taken and added to fresh tubes of gelatin or agar, mixed, and roll cultures made at once, or it is poured out into Petri dishes. After incubation the colonies are counted, and the number appearing in 1 c.c. of soil is computed. Anaerobic microörganisms must be cultivated in the absence of oxygen.

Fraenkel's earth drill (Fig. 24) is used to obtain soil samples from greater depths. Above the point on this drill is a small box, which should previously be sterilized and which can be opened or closed at any depth.

In the upper layers of soil spore-forming bacteria are principally found (*Bacillus mycoides, B. subtilis, B. mesentericus, etc.*). Spores do not appear to occur in deeper layers. Of the saprophytes we find streptothrixes and proteus organisms as well as nitrifying bacteria which assimilate the free atmospheric oxygen. Microörganisms (nitrobacteria) take an extremely active part in the disintegration of organic matter in the soil which is the foundation for the cycle of elements. The nitrite-forming bacteria (*Nitrosomonas*)—thick, usually short, plumb bacteria—oxydize ammonium combinations to nitrites; the nitrate formers (nitrobacteria)—short, very small, plump rods—change the nitrites to nitrates. Nodule bacteria were mentioned on page 51. A convenient insight into the cycle of carbon and nitrogen in nature is given in the diagrams which appear

as Figs. 25 and 26. Among pathogenic bacteria, the tetanus and malignant edema bacilli are nearly always found in the upper earth layers, which are rich in organic matter. This is verified by animal experiments. Under certain conditions the bacteria of anthrax, blackleg, erysipelas, etc., occur and multiply in the soil; as, for instance, in the case of excreta of sick animals, carcasses of animals that have

Fig. 24. Ground borer.

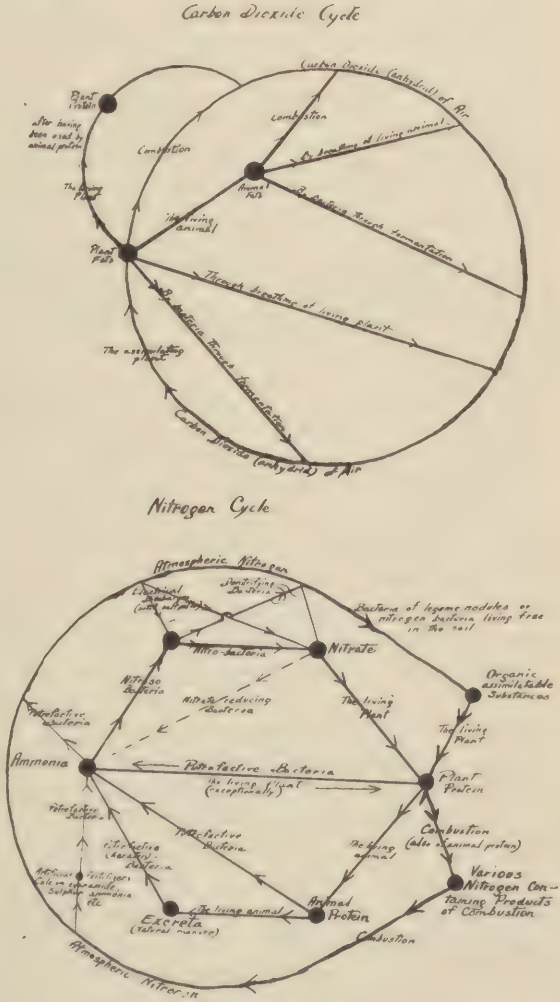

Fig. 25 and 26.

died of infectious diseases, and the products of such carcasses, as well as infected fertilizers of animal origin (waste products from horsehair works, tanneries, etc.), and as a result of floods from rivers infected by tanneries (page 75). Sporulation of anthrax and blackleg bacilli occurs only in the upper layers of earth to a depth of 1.5 me-

ters (5 feet) during the summer months, June to August. Other pathogenic bacteria can also remain virulent in the soil for a greater or lesser period; the tubercle bacillus in carcasses 3 months, rabies virus 2 to 3 weeks, *Bacillus typhi* 3 months. Eggs of tapeworms and nematodes, etc., also frequently occur in the soil.

A porous soil containing a medium amount of moisture (bogs, swamps, bottom lands), considerable impurities (organic substances) and sufficient warmth (in upper layers) is favorable for the development of pathogenic microörganisms. When the soil is very much polluted, there is danger that pathogenic germs may be brought to the soil with polluting refuse. Pollution can therefore be the source of infection. The conditions required for the growth of pathogenic germs are as a rule not present in the deeper layers of the earth. For example, the anthrax bacillus will seldom develop at a depth of 2 meters (slightly more than two yards) even when favorable culture medium is present; and at a depth of 3 meters it will not develop at all. The development of spores of pathogenic bacteria is also usually impossible at these depths, because of the low temperature and oxygen tension.

Danger of infection by living disease-producing germs can therefore occur as a rule only when they are present in the upper layers of the soil. Those at greater depths as a general rule can not reach the surface. The air in the soil is never able to carry germs upward. Ground water, which tends to be free from germs, can only exceptionally carry pathogenic germs from the depths through wide crevices in the earth to wells and springs and in that way induce infections. On the other hand, the water movements in the capillary pores of the ground, which are directed toward the surface (rising of the ground water) are never adapted for transporting bacteria to the earth's surface. This is regardless of the fact that during the so-called "rising" of the ground water, an upward movement of the water as a general thing really never occurs, but instead the level of the ground water approaches the earth's surface because of the surface water draining into the existing ground water. Even when an actual rise of the ground water results through lateral tributaries, which, probably, is possible only when complicated geological and meteorological conditions exist, the resulting elevation of the pathogenic germs in the deeper layers of the earth would be opposed by the high surface action of the ground. Pasteur also attributed the rising of the bacteria to the earth's surface in part to angle worms[1], but this is a moot question on which opinions vary. Plowing, harrowing, digging ditches, etc., are no doubt more important. Bacteria are most certainly brought to the earth's surface in this way.

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[1] According to Brehm, angle worms bore into the ground 5 or 6 feet. Regarding moles he says that they live 30 to 60 cm. (1 to 2 feet) beneath the ground surface. On the other hand water rates (muskrats?) do not come under consideration here, since their long passages are found immediately beneath the surface of the ground.

Inasmuch as the microörganisms in the upper layers of the earth (which are almost without exception of the greatest importance from the standpoint of infection) are exposed to various injurious atmospheric influences, only spores as a rule are able to remain infective; they take a very important part in the tranmission of "soil diseases."

The transmission of pathogenic microörganisms occurring in the soil results in part (especially in anthrax) from the feed (green forage, hay, tubers). The bacteria settle on the feed with the dust, or are splashed there by heavy rains, or are conveyed with the small, adherent particles of earth. Pathogenic bacteria (such as the bacilli of blackleg, anthrax, etc.,) may also gain entrance into wounds by means of filth (also to wounds of the oral mucous membrane through defects of teeth) and injuries (principally when driving animals from pasture), or are transmitted by insects. (Wind can carry away infectious dust or carry it directly or indirectly to the animals.) Water seems to play a less important part in transmitting soil diseases to farm animals, whereas it plays an extremely important rôle in the infection of people with abdominal typhoid fever and cholera. Transmission may also occur by shoes or implements of persons who walk over the infected ground or who till it, as well as by animals.

The danger of infection is greatest during the fall months, when the ground water is at its lowest level. This is not due, as was at one time thought, to the bacteria being carried upward by the air currents in the soil as a result of their being released by the soil moisture following the lowering of the zone of evaporation, but rather other conditions must be taken into consideration as a cause of this increased danger of infection. The warmth may leave the earth very slowly, so that a marked proliferation and sporulation of pathogenic microorganisms results in the soil. Furthermore, when the level of the ground water is at its lowest a dry zone tends to develop at the surface, and precipitations penetrate only a few millimeters, so that all the soil impurities remain in the uppermost layers of the earth. In this manner greater opportunity exists for the transportation of disease than if the soil were thoroughly moist, and a developing precipitation (rain) would quickly wash off or flush the filth into the depths, which would remove it from traffic. In the fall the various tubers are harvested, animals are brought in from pasture, more or less in many localities, and in these ways the opportunities for transporting pathogenic soil bacteria and for spreading infection are increased. The upper layers of earth in swampy regions become exposed when the ground water sinks, and in case anthrax spores are present they will sporulate when oxygen is accessible, and the resulting bacilli rapidly multiply if sufficient moisture is present and in time develop new spores.

Many diseases of man and animals have a close relationship with

the soil and are therefore designated as "soil diseases." Certain infectious diseases are included in this group, such as anthrax, blackleg, tetanus, malignant edema, etc. Certain epizoötic parasitic diseases may be included, such as distomatosis, lungworm disease, stomach-worm disease, sclerostomatosis in horses, tapeworms in sheep, ancylostomiasis of miners, as well as non-parasitic diseases such as licking diseases and brittleness of bone. Finally malaria, piroplamoses and trypanosomiases bear a close relationship to the soil in so far as its condition favors the occurrence of the intermediary hosts of the respective blood parasites. Chicken cholera, erysipelas, hemorrhagic septicemia of cattle, malignant catarrhal fever, etc., are frequently looked upon as originating in the soil.

Parasitic soil diseases may be prevented by avoiding infecting the soil. The excreta and carcasses of animals which were affected with anthrax, blackleg, erysipelas, etc., should be disinfected or burned, or, if these are impossible, properly buried.[1]

For the purification and clarification of the waste water from tanneries, Rohland[2] recommended a procedure, dependent upon the drainage of the soil in order to retard the development of pathogenic microorganisms and worms. A systematic drainage of soil has often proved the correct expedient for controlling anthrax and blackleg, likewise for regulating a river in bottom lands. In emergencies soil infected with anthrax and blackleg should not be used for pasturing and should be planted with trees (see "Pastures").

[1]The German Federal Council on Animal Disease Laws (1911) requires that a locality be selected that is high, dry, sufficiently distant from homes, stables, wells, watering places, meadows and open highways. Whenever possible, soil containing humus, loam, or clay, localities having many springs, gravelly or sandy regions which are or could be exploited, as well as places where the ground water does not stand at least 2 meters (slightly more than two yards) under the earth's surface, are to be avoided. The place of burial should be so arranged that it will be impossible for horses, ruminants, hogs and dogs to get at it. The carcass or parts of carcass are to be buried sufficiently deep so that at least 1 meter (about one yard) of earth covers it when the grave is level with the surrounding land. Before burying the carcass the hide is to be rendered worthless by slashing in numerous places. Deep gashes should be cut into the carcass and then covered with lime or tar. After the carcass is in the grave all earth and sod on which blood is found should be buried with it. Graves in which carcasses, etc., of animals dead from an infectious disease or suspected of having died of an infectious disease are buried are not allowed to be reopened except by permission of police officials.

[2]Rohland. Deutsche Tieraerztl. Wochenschr., vol. 23, p. 376.
Winterberger. Wiener Tieraerztl. Wochenschr., vol 2, p. 353.

Section III

Water

Water is an indispensable nutritive substance. Life and health are dependent on a closely defined water content of the organs. Even slight variations in the water content of the cells will produce disturbances in metabolism and in the general state of health, and in time will cause serious diseases. Experiments have shown that when insufficient water is taken up gastric digestion and absorption are retarded and the nitrogenous metabolic substances are retained longer in the body. Young and growing animals suffer in growth and development if they are deprived of but small amounts of water. When the blood becomes thick fever develops as well as an increase in the decomposition of the protein and fat. A continuous insufficient water supply causes an aversion for solid food and results in vomiting and diarrhea. A loss of 10 per cent of water will cause restlessness, trembling and weakness; a loss of 20 to 22 per cent will cause death through thirst. Absolutely depriving animals of water causes death in about 10 days; deprivation of food causes death in about 40 days.

The amount of water necessary for the body is taken up in part with the feed. Feeds that contain much water (fresh green forage, turnips, residue rom the distillation of alcoholic liquors, etc.) will supply the total amount of water necessary. Water is taken up by the body in part as such, and partly it results from the oxidation of the hydrogen which is chemically bound to the substances of the feed (according to Voit about 16 per cent of the total amount of water eliminated).

Water is not only a food but also a very important cleansing substance. A plentiful water supply has always been highly appreciated by all cultured peoples and has been made the subject of their greatest engineering achievements, as was mentioned in discussing ancient times in the brief historical sketch in the introduction.

A. The General Condition of Drinking Water

I. Ground, Spring and Well Water

The origin of ground water was shown on pages 60 and 61. The precipitations penetrating into the ground will first take up a quanity of waste matter, in either a dissolved or suspended state, which occurs in the superficial, polluted layers of the earth, and which

spoils the quality of the water. As the water penetrates further through the ground the suspended substances as well as the micro-organisms are filtered off and the dissolved substances for the most part given up. The organic substances serve partly as food for the plants and microörganisms, the latter rapidly decomposing ("mineralizing") them, with the exception of humic substances, which are more resistant. Waste matter will penetrate to greater depths or even to the ground water only if the water flows quickly through the upper layers (gravel, crevices in the ground, etc.), or when the ground is supersaturated. The inorganic substances (phosphates, potassium) will partly become bound chemically and serve as food for the plants and bacteria, and a part of them pass through the ground (chlorides, a great many of the sulphates, nitrates resulting through bacterial activity on nitrogenous substances, as well as nitrites, ammonia and even organic substances which occur when insufficient oxygen is being admitted and the ground is very much polluted). As a general rule, the farther the water has to pass through the soil the freer will it be from dissolved waste substances. Therefore the water from the greater depths is generally purer (from a hygienic point of view) than water nearer the surface. In its passage through the ground, water takes up carbonic acid, enabling it to dissolve silicates as well as difficultly soluble or insoluble carbonates (lime, magnesium, iron), the latter as double carbonic acid salts, e. g., $CaCO_3+CO_2+H_2O=Ca(CO_3H)_2$. At greater depths the water attains a constant low temperature which makes it more palatable. After water becomes vitiated it later improves again.

If the soil is much polluted, chlorides, nitrates, nitrites and ammonia and even organic substances occur in the ground water, especially in supersaturated ground, but no bacteria, or at least only a few, according to the level of the water. If water precipitated during a day should become directly mixed with the ground water through wells that are not watertight or through crevices in the ground, without previously passing through the ground, no filtration of the microörganisms and other suspended matter will take place, nor any decomposition of organic matter. Impure water of this character contains many bacteria as well as organic matter, mostly ammonia. Such direct additions are far more serious from a hygienic standpoint than impurities that have been filtered through the ground.

The chemical composition of the ground water is subject to great variations. The quantity of dissolved substances originating in material which pollutes the soil, is shown in the following table in milligrams per liter of water (1 liter equals 1000 c.c., or about 1 quart):

	Minimum	Maximum in pure water	Maximum in impure water
Organic Matter	0	40	1300
Oxygen used for oxidation	0	3	100
Ammonium	0	Traces	130
Nitrous acid	0	Traces	200
Nitric acid	1	15	1300
Chlorids	4	30	900

Furthermore, the chemical composition of the water depends largely on the character of the stone in the ground. One liter of water contains in milligrams the following:

Source of Water	Evaporation residue	Sulphuric acid	Lime	Magnesium	Deg. of hardness	Chlorin	Nitric acid
Granite formations	24	3.9	9.7	2.5	1.27	3.3	0
Colored sandstone	200	8.8	73.0	48.0	13.96	4.2	0—9.8
Shell lime	325	13.71	29.0	29.0	16.96	3.7	0.21
Dolomite	418	21.01	49.0	65.0	23.1	Trace	2.3
Gypsum	2365	1108.37	66.0	122.5	92.78	16.1	Trace

Besides the dissolved chemical substances indicated in the foregoing table (e. g., organic matter, ammonium, nitrous acid, nitric acid, chlorids, sulphates, lime, magnesium) the water also contains oxids of potassium and sodium, silicic acid, carbonic acid and iron; also clay, iron-oxid combinations, lower forms of animal life, algæ, bacteria and other vegetable life.

When ground water comes to the surface spontaneously it is called spring water. If it is brought to the surface artificially it is called well water. Spring water as a rule comes from the deeper ground layers. Its purity, as well as that of well water, is dependent on the condition (filtering quality, cleanliness, etc.) and depth of the ground layers through which it passes.

II. Rain Water

Rain water is very soft and is advantageously used in the household (washing, cooking of vegetables) when only very hard water is otherwise available (not considering cases where there is a deficiency of other water).

When rain water passes through the air it takes up considerable dust and with it microorganisms, organic substances, traces of sodium chloride, lime salts, minute particles of iron and carbon, ammonium combinations, nitrous and nitric acid, sulphurous and sulphuric acid, carbonic acid, nitrogenous organic combinations, small quantities of hydrogen peroxid and particularly oxygen and nitrogen. The dry substance content per liter is about 20 to 50 mg., consisting of about equal parts of organic and inorganic matter. Rain water has a flat taste because it contains so little carbonic acid and mineral substances. The organic matter mixed with it makes it possible for rain water to putrefy, but this condition does not last very long.

III. Water of Streams, Lakes, Pools and the Sea

The water of brooks, rivers, lakes (natural and artificial), pools and the sea is made up partly of spring and ground water, partly of rain water, and in many instances it also contains sewage and waste from homes and industries. Spring water, which is more or less clean as well as rich in carbonic acid, lime and magnesium salts, and therefore hard, loses a part of its carbonic acid while it flows in brooks and rivers over the earth's surface, in that the bicarbonates of lime, magnesium and iron are transformed to monocarbonates. The resulting monocarbonates are far less soluble than the bicarbonates and are therefore precipitated to a great extent, which causes the water to become softer. Water is likely to be pure and can be used for drinking and other purposes without danger as long as it flows only through wooded, uncultivated and sparsely populated districts. However, during its subsequent course it becomes contaminated with dissolved and suspended organic, putrescible substances and bacteria. Rain water which has flowed over fertilized fields and carries with it a great deal of filth and waste matter from towns, flows into streams. Where the rivers flow past towns or cities, very frequently the entire sewage and foul, poisonous waste from industries are discharged into the river. The polluting organic substances are partly consumed by the action of bacteria and other forms of vegetable life (algæ, saprolegnia, etc.) and various animals (*Infusoria, Rotatoria, Turbellaria, Rhizopoda, Crustacea, Cyclops, Daphnia*, etc.). Some of these substances settle to the bottom and help to form slimy banks. In that way the organic and suspended impurities separate out again more or less and the greatly increased numbers of bacteria and other low forms of life die, partly through lack of nourishment, partly as a result of the disinfecting action of sunlight, etc., and partly they serve as food for aquatic animals. The germ content of the water is thus again reduced to about the same proportion as before the pollution.

The entire process of removal of water pollution is designated as "*self-purification*," just as in the case of the soil (see page 62). The process of self-purification is to be regarded as completed when the water has regained the same chemical and biological conditions which it had previous to pollution and when the river bed is again as clean as it was before the drainage water was introduced. The time required will depend upon the degree to which the polluting material is diluted with pure ground, brook or river water, the velocity of the current, the nature of the river bed, the nature of the pollution, the species of living organisms found in the water, the temperature, etc. River water does not become fit for use through self-purification.

Most of the pathogenic microörganisms which gain entrance to

river water die very quickly. A few species (anthrax spores, typhoid and cholera bacilli) can remain alive for a great length of time in the slime of the river bed and in the water if the latter contains a good deal of organic matter (cholera bacilli). Contaminated river water is very dangerous for use in the household, especially as drinking water, the danger being greater in proportion as the point at which the water is drawn is near to the point of entrance of the bacteria. Infected river water can also infect meadows and fields when they become flooded (anthrax spores, see page 67).

Lake water is usually pure from a chemical and bacteriological standpoint. The suspended matter and bacteria brought to the lakes with inflowing water settle almost completely in a very short time. Even here great variations occur. Water is naturally purer when the shore is thinly populated (mountain lakes) than it is in the neighborhood of cities and industries. Whenever lakes are to be used as a source of water supply, each case must be judged according to conditions. In some instances the water may be used for drinking purposes without restriction. If there is any danger of the lake water being infected it should be classed with polluted river water. The temperature of the surface of standing water is decidedly influenced by the warmth of the air and the rays of the sun. However, at depths from 12 to 15 meters the water temperature is quite constant and low (4 to 9° C., 39 to 48° F.). The point from which lake water is to be drawn should be as deep and as far removed from the turbid area as possible, the latter being caused by the waves.

Water of *artificial lakes* is to be regarded the same as other lake water. The water of *ponds,* according to their location and size, is sometimes more like that of a pool and sometimes more like that of a lake.

Standing water of *puddles* and *pools* usually contains a great number of living plant and animal organisms, among which very often pathogenic germs occur. The water itself, and particularly the bottom, is full of organic matter which is often in an active state of decomposition. Water in the neighborhood of farms is frequently polluted by liquid manure and by sewage from the house. Such water is not suitable for drinking or other purposes.

Sea water contains about 35 grams of salt per liter (of which there are 27 grams sodium chlorid besides chlorids of potassium and magnesium, sulphate and carbonate of lime and magnesium, as well as iodids and bromids). The high salt content of sea water precludes its use as drinking water. Many cattle have been observed to become sick after drinking sea water.

B. Hygienic Requirements for Drinking Water[1]

Water intended for drinking water and other use should be: (I) free from causes of disease, (II) palatable, and (III) sufficient in quantity.

I. The most important requirement for any drinking water is that it be *free from causes of disease.*

The following may cause disease: (1) Chemical poisons (lead, arsenic, zinc, etc.); (2) Vegetable microörganisms (bacteria); (3) Animal organisms (development forms of intestinal worms, etc.).

Incidentally, abnormal low temperatures may also be mentioned.

Lead has been detected most frequently of all *chemical poisons* in the water. It seldom originates from the ground. Sometimes it gets into the water from industrial plants (lead smelters, etc.), or it is taken up by soft water from lead pipes[2]. Water containing oxygen and carbon dioxid is especially liable to affect lead quite strongly. The presence of humus acids (which frequently occur in ground water to a considerable extent) and nitrates also favor this action. On the other hand, chlorids and particularly carbonates hinder the dissolving action of lead. Hard water can be conducted through lead pipes without hesitation.

Water containing lead has repeatedly caused poison, sometimes directly and sometimes by means of the soil and forage (turnips). Instances of lead poisoning, frequently leading to death, have been observed in horses, cattle, goats, dogs, fowls and fish. (For symptoms of poisoning see "Damage Done by Smelter Smoke.")

During the last ten years no cases of arsenic poisoning have been reported. Formerly when arsenic combinations were used more frequently in various industries (anilin dye works, tanneries, etc.) greater opportunity existed for polluting water with arsenic and in this manner causing poisoning. Wilhelm reports cases of copper poisoning.

Przybilka reports one case of zinc poisoning. Grazing cattle which drank from water holes into which calamin (hydrous zinc silicate or zinc carbonate) water flowed suffered from colic and diarrhea which lasted for several days. Geese and ducks were affected with staggering and drooping of the head, followed by death.

It has not been definitely shown that drinking water which contains many nitrates, gypsum or iron is liable to injure the health of domestic animals, as Reichardt and Maercker assume. It is certain that water containing iron is frequently used without bad effects, even though colic caused in horses from drinking such water has been reported (Ludewig). On the contrary, Eiler demonstrated that

[1]Water which is used for washing forage, mangers, feed boxes, etc., should be free from causes of disease, the same as drinking water. On the other hand, the taste and temperature of the water are not of such great importance.

[2]The passage of lead into pipe water has frequently been observed in Germany and has often caused lead poisoning.

iron even in quantities of 0.3 grams to 1 liter of water was not injurious. If at the same time it contains an unusual amount of lime and magnesium salts, especially in the form of chlorids, less carbonates than usual and no nitrates, it is said to irritate the liver.

Very soft water (containing very little lime) may favor the development of bone diseases (halisteresis ossium: softening and brittleness of the bone). Water of medium hardness is best (10 to 20°).

Water which contains a great deal of organic matter and the products of decomposition is often used without bad effects, but at times may cause gastroenteritis, symptoms of excitement and paralysis, and even death (Tietze, Serling, Gueckel, etc.). In such cases the noxious cause is more likely to be found in certain species of bacteria than in chemical poisons.

The waste water from tanneries is harmful to fish because the water contains tannoides and their derivatives (phlobaphenes, etc.). In Germany tanneries are therefore required to have basins for clarifying the water.

If sand is frequently taken up with drinking water, as when the water is obtained from shallow places having a sandy bottom or subsoil, it may lead to the following disorders, particularly in horses: Collection of sand in the colon, causing nutritional disturbances; intestinal catarrh; sand colic; kinking of the intestine; volvulus, and even fatal enteritis and necrosis of the mucous membrane.

Of the many *pathogenic bacteria* which may gain entrance into water, those causing cholera and typhoid fever in man are of most importance. Bacteria pathogenic to animals are seldom widely distributed by means of water; as a general rule they can not multiply in the water. Sporadic observations have been made where water was the disseminating medium of infection, e. g., fowl cholera (water fowls), rabbit septicemia, anthrax (brook water, which is primarily contaminated by tanneries, less frequently by well water, contaminated river water is seldom a direct cause of anthrax, but the disease more frequently occurs through forage becoming contaminated during floods; see discussion of anthrax-infected meadows), swine erysipelas (wash water from the meat of sick animals slaughtered in emergency, as well as contaminated brook water), also *Staphylococcus* and *Streptococcus pyogenes*. The belief that epizootic cerebro-spinal meningitis is spread by means of water is probably erroneous. Campbell states that acute infectious laryngitis of horses, mules and cattle was caused through contaminated water. Bacteria pathogenic to fish and crabs should also be mentioned, such as the cause of furunculosis of the genus *Salmo* (brook trout, etc.), *Bacillus salmonicida;* the cause of crab plague and scale ruffling of white fish, *B. pestis astaci;* the cause of "red plague" of carp, *B. cyprinicida;* bacteria of "red plague" of eels, salmon plague, "jaundice" of roaches (fish), etc.

Of the various *animal parasites* which are transmitted by the water and which are pathogenic to fish, are the following protozoa: *Myxobolus cyprini* (smallpox of carp), *M. pfeifferi* ("boil disease" of barbels), and other species of *Myxobolus* (nodular diseases); *Costia necatrix, Ichthyophthirius,* etc. Likewise the eggs and embryos of many intestinal worms may be transmitted to domestic animals, chiefly through standing water (pools and puddles); for example, Oxyuridæ, Trichocephalidæ, Strongylidæ (*Strongylus equinus, Metastrongylus apri, Hæmonchus contortus, Dictyocaulus viviparus*), *Setaria equina, Habronema megastoma, H. microstoma, Dioctophyme renale,* eggs of *Tænia echinococcus, T. solium, T. saginata,* and *Bothriocephalus* (cercariæ or larvæ of distomata). Almost without exception they do not occur in flowing water. In order to prevent the serious and often fatal worm infestations it is advisable to drain pools and swampy pastures or prevent swampy ground from being used for pasturage, and to feed the grass only when it is dry and has aged for some time (see "Pastures and Exercising Lots").

The consideration of an *abnormally low temperature* of the water is also of importançe. Reports are often seen in literature of cases in which the drinking of cold water, particularly by horses, has caused abdominal pains, colic, diarrhea, rheumatism, laminitis, even cerebral and pulmonary hemorrhages, and abortion in cows well advanced in pregnancy.

II. Water should be *palatable* in order that it will be willingly taken. While the demands for a good drinking water for human consumption are refreshing taste, freedom from odor, or color, clearness, the absence of an aftertaste and of coarse, visible impurities, and also a temperature of 7 to 12° C. (45 to 54° F.) if possible, naturally no such high demands are made for the drinking water for animals. If the water is free from all odor of decomposition or other odors, free from decay or moldy taste, free from marked turbidity and coarse impurities, and if it is willingly drunk by the animals, there is no reason why it should not be used as drinking water. Naturally, it is best to give the animals as pure water as possible.

III. A *sufficient quantity* of water should be available to satisfy the thirst of the animals and to provide for cleaning the animals and the stable so as to remove many causes of disease.

C. Examination and Testing of Water

In examining water the chief questions that are to be determined are whether the water is fit for establishing a water supply or whether a certain disease was caused by drinking the water. None of the natural water supplies will be satisfactory in all respects from a hygienic standpoint, therefore a special examination should be conducted in each instance. Such an examination should include (1) the so-called preliminary test, (2) examining the locality, (3) chemical

examination, (4) microscope and bacteriological examination. The inspection of the locality should be chiefly concerned with determining the possibility of infection. The bacteriological examination proves whether the water is actually free from germs or whether it contains certain infectious matter.

The chemical examination gives information as to the origin, palatability or poisonous character of the water. In case the veterinarian lacks the necessary experience or time, he should have the chemical and bacteriological examinations made by someone else; but he or the hygienist should reserve the right to pass final judgment as to whether the water should or should not be used.

I. Taking the Sample and Making the Preliminary Test.

It is exceedingly important that the sample of water be obtained in the correct manner, therefore an expert should do it whenever possible.

In order to avoid any unforseen events in *obtaining the water* the following should be strictly observed:

When taking a sample of water from pipes, it should first be allowed to run for 20 minutes. However, if the water is to be examined for lead, the very first water that comes from the pipe should be used as a test sample. Well water should be pumped for 15 minutes before taking the sample, in order to cleanse the water pipe thoroughly. The bucket of a bucket well should first be rinsed several times with the well water. The best manner of obtaining water from a river, pond or brook is to dip a bottle into the water in an inverted position, and then, after it is deep below the surface, turn it up without stirring up the dirt on the bottom. When obtaining samples of spring water no special precautionary measures need to be observed.

Transparent, colorless glass bottles should be used in obtaining the water samples. Colored glass bottles, earthenware or porcelain jugs, etc., are not suitable, since it is difficult to be sure that they are actually clean. If the water is to be examined chemically, in which case 2 to 3 liters (quarts) are necessary, the bottles should be cleansed and rinsed several times with the water that is to be examined. The bottles are closed with a tightly fitting ground glass stopper, previously cleansed in a similar manner. In emergency a thoroughly scalded cork may be used, the top being covered with parchment paper. In case the water is to be examined bacteriologically, the previously cleansed bottle and stopper should be boiled for fifteen minutes in order to sterilize them (beginning the boiling with cold water and covering the bottom of the dish with excelsior, cloth or other material). After it has cooled the bottle should be rinsed with the water that is to be examined and then filled. If the bacteriological examination can not be carried out within 1 to 2 hours, the

bottle should be packed in ice in order to prevent the multiplication of the bacteria as much as possible.

If the bottles are to be shipped to a laboratory they should be sealed and marked to give the locality, time of taking the sample, and temperature of the water and the air.

The *preliminary test* includes the temperature, odor, taste, color, clarity, presence of carbonic acid and the reaction of the water. This is usually done when taking the sample of water for a chemical and bacteriological examination.

The *odor* is usually made more distinct when the water is heated to 60° C. (140° F.). Changes occur with admixtures of decomposition products (always very dangerous), drainage water from industries, etc. If the ground contains a great deal of humic substances, brown coal (lignite), etc., the ground water frequently smells of sulphur compounds (disagreeable but harmless). The odor is often more distinct than the chemical reaction.

The *taste* of the water is greatly influenced by the temperature and the content of lime, carbonic acid and oxygen. The most desirable temperature for the water is between 7 and 12° C. (45 and 53° F.). Warmer water is not refreshing, and colder water is often injurious. Since a different taste is frequently not distinctly noticeable until the temperature is 12 to 20° C. (53 to 68° F.), the taste should also be tested at that temperature. When the taste is salty it indicates an increased content of sodium chlorid or potassium chlorid. Sodium chlorid must be present to the extent of 420 mg. to the liter of water and potassium chlorid about 240 mg. to the liter before it can be tasted. These quantities are of no consequence from a health standpoint. Water is bitter when it contains magnesium sulphate (Epsom salt), potassium sulphate or magnesium chlorid. Magnesium sulphate can be tasted when it is present to the extent of only 1 gram to the liter of water, whereas magnesium chlorid can be tasted when only 50 to 100 mg. to the liter is present. Water containing a great deal of iron has an astringent taste, similar to ink. Admixtures of putrefactive products produce a putrid, moldy taste; these should never be present in water.

For judging the *color* and *clarity* of water it is poured into a colorless glass cylinder up to about 40 cm. and observed against a white background. By comparing it with distilled water under the same conditions the slightest discoloration or cloudiness can be seen. River water is yellow as a result of the admixture of loam or clay, which also causes it to be turbid. Ground water from marshy land is frequently colored brown through humic substances (cannot be filtered off and is unimportant) and yellow from iron. Iron is dissolved as iron oxid (principally bicarbonate of iron) in ground water. When water containing iron is allowed to stand exposed to the air, or if it is heated, the carbonic acid of the bicarbonate is lost and the iron-oxid

combination is oxidized and separates out as brown flakes of ferric oxid hydrate. This causes the water to become turbid and forms a yellow scum on the surface and a rust-colored precipitate on the bottom, which can be easily broken up in the water. (Water containing iron can not be used for washing or for making tea or coffee.) *Crenothrix* (Figs. 27, 28, 29) easily develops in water containing iron or manganese. Its whitish fungous growth becomes colored brown through infiltration with iron and increases the turbidity of the water and may clog the pipes. In water where fish occur *Crenothrix* often develop on the outer skin and on the gills of the fish (carp) and may kill them. Manganese combinations may also occur in such great quantities in the water that they separate out when they come in contact with air. They cause the same disagreeable conditions as the iron combinations. Although iron can be removed easily (page 104), removal is far more difficult in the case of manganese. Since manganese is not of much importance to health it is of little consequence in the drinking water of animals. Rarely a green discoloration of water is observed. When this is seen it is attributed to algæ (*Oscillaria viridis*).

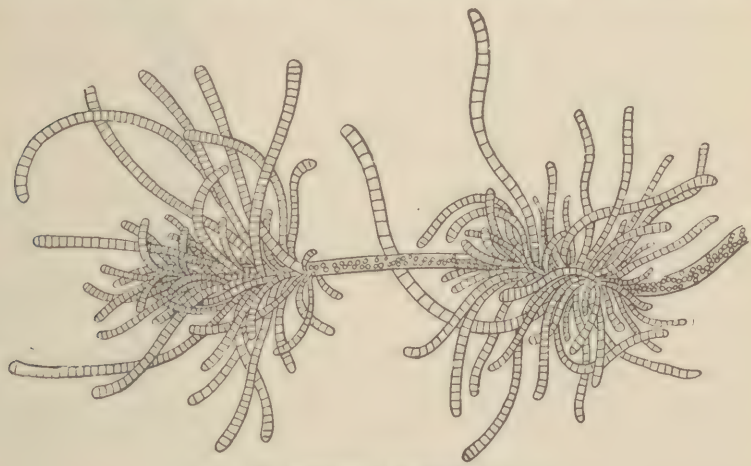


Fig. 27. Crenothrix polyspora (1:150).

Turbidity of water is partly caused by living matter (microörganisms) and partly by inanimate matter held in suspension (loam, clay, grains of sand, etc.). The inanimate matter gradually settles out when the water is quiet, but the living forms very frequently remain in suspension by their own motility.

In estimating the amount of matter in suspension, 2 to 3 liters of the water in question is poured through an ash-free, dried filter, whose weight was previously determined; the filter with the precipitate is dried at 102° C. and then weighed. If the amount of inorganic matter is to be determined the filter is burned to ash in a platinum crucible and then heated until it glows, this to be continued until all organic substances are burned. After the crucible has cooled it is weighed.

Testing for *free carbonic acid* must be done in the preliminary test, as this substance will escape upon standing. The test is carried out by adding 5 to 10 drops of a 1 per cent phenolphthalein solution in 96 per cent alcohol, which has been colored red with one drop of normal alkali (to 100c.c.), to about 100 c.c. of the water. If the phenolphthalein is decolorized, free carbonic acid (or free acid) is present. If this decolorization no longer takes place after boiling the water, it proves that free carbonic acid caused the original decolorization of the fresh water.

The *reaction* of most water is neutral upon testing with litmus paper. Water that is alkaline must be looked upon with suspicion (putrefactive products). To determine the reaction a strip of litmus paper is placed in the water in question and at the same time a strip is placed in distilled water; comparison is then made of the color change.

Fig. 28. Crenothrix polyspora (1:200).

Fig. 29. Piece of an old Crenothrix thread colored brown by iron.

II. Examination of the Locality

When examining a locality one should determine whether there are any common or very ordinary means of polluting the water, and whether any possibility exists for contaminating the water. The local inspection is in this respect usually more satisfactory than the bacteriological examination, and always better than the chemical tests, which are often ambiguous.

When water of a *pond, lake, brook* or *river* is under consideration, particular attention should be paid to whether animal or human excreta, drainage water from homes, etc., can reach such water; whether water fowls live on the water, whether domestic animals graze on the shores and have free access to the water, etc. If an open stretch of

water is free from habitation, the possibility of contamination is nevertheless to be considered, but its probability is almost nil.

In the case of *spring water* it is necessary to determine whether it does not originate from a superficial water course, whether fertilized meadows are not within the drainage area of such a water course, and whether any connections exist with brooks or rivers. Subterranean connections may be determined by pouring solutions of fluorescin (uranic potash) or saprol (which may be recognized even in dilutions of 1 to 1,000,000 in that they taste similar to illuminating gas or naphthalene), salt or suspensions of yeast or *Bacillus prodigiosus*, etc., into the source of the water from which a pollution of the spring water is suspected, and afterwards testing the spring water for the presence of any of these agents.

In examining *well water* (page 97) the following should be taken into consideration: The location of the cesspool, privies, manure piles, sewerage, drains, ditches, stables and pools; topography (whether surface accumulations of water can drain toward the well); nature of the ground surface (pavements, etc.); whether the well-curb is higher than the ground; whether the masonry in the well is without defects; whether there are any defects in the covering or connections of the well or pump; the nature of the subsoil (whether the pores are fine or coarse); the level of the ground water, and in which direction it flows. In order to be sure the well should be uncovered if possible and the shaft or pit examined with a light. The seepage of water can be detected by the dark or whitish stripes on the sides of the walls. In case moths fly out, which are found in the open only at night, this indicates that there are openings which should not be present. Foreign bodies, such as dust, dead butterflies, etc., found floating on the water, indicate that the well covering is not tight. On the other hand, if a scum with a bronze-like luster appears on water containing iron, this is to be regarded as of no importance. If such a simple examination does not explain the source of a strongly suspected pollution, then fluorescin, etc., may be used to determine the source of the suspected contamination, as has been explained with regard to testing spring water.

III. Chemical Examination of Water

The method of taking a sample of water for making a chemical examination is described on page 79. Regarding substances that are in solution or simply in suspension, we must consider, first, those whose mere presence in the water are injurious (lead, arsenic, etc.) or which render the water impure (nitrous acid, ammonia); and secondly, those whose presence is to be regarded as a pollution only if the amount of foreign substances (chlorids, sulphates, nitrates) is greater than in water having the same origin and which has been proved to be pure. In the first instance a qualitative analysis is suf-

ficient, in connection with an approximate estimation to be made later, whereas in the latter instance a quantitative determination must be made. In the following discussion only such tests and determinations are considered as are more easily conducted and relate to substances which possess greater hygienic importance. For analytical methods outside of this scope, the reader is referred to Beythien (*Handbuch der Nahrungsmitteluntersuchung,* published by Beythien, Hartwich and Klimmer, vol. 1). The different constituents in the water are generally expressed in milligrams per liter, i. e., parts in a million.

1. Gases

With regard to testing for *carbonic acid gas,* see page 82. *Hydrogen sulphid* is easily recognized by its odor (page 80). For a *chemical test* the water is heated in a flask to the boiling point, having a piece of filter paper soaked with lead acetate fastened in the neck of the flask with a loosely fitting cork. If this paper turns black, due to lead sulphid, this indicates the presence of hydrogen sulphid. By renewing this slip of paper and by adding 5 c.c. of sulphuric acid, the presence of sulphid can also be determined.

If the water is to be used for raising fish, it is important to determine the amount of oxygen absorbed by it.

Oxygen as well as carbonic acid may attack iron and lead pipes. It is well known that free carbonic acid destroys iron pipes. Even dissolved oxygen may cause very marked corrosion in the absence of carbonic acid. Water which contains even 5 c.c. of oxygen per liter is harmful.

The oxygen determination should be made immediately after the sample of water is taken. The following method (Winkler's) is practicable only in the absence of nitrous acid and iodin:

Principles of the Test: Manganous hydroxid is converted into manganic hydroxid through free oxygen, and by subsequently treating it with hydrochloric acid it is converted into manganic chlorid. Manganic chlorid will liberate from potassium iodid a certain amount of iodin, proportional to the amount of oxygen present at the beginning, the iodin being determined with a solution of sodium thiosulphate.

Method of Test: A 250 c.c. flask is filled with water. With a pipette one-half c.c. of a solution of potassium iodid and sodium hydroxid (10 grams potassium iodid in 100 c.c. of a 33 per cent solution of sodium hydroxid) is introduced at the bottom of the flask, also one-half c.c. of manganese solution (80 grams of manganous chlorid in 100 c.c. water). The flask is then closed so that no air will be present in it, and is then thoroughly shaken. After the precipitate has settled down the flask is opened and 5 c.c. of pure fuming hydrochloric acid is introduced at the bottom without disturbing the precipitate. Close the flask as before and shake it slightly. After the precipitate has dissolved the contents are measured and poured into a beaker, and this liquid, which has turned yellow because of the iodin, is titrated with $\frac{1}{100}$ normal sodium thiosulphate solution (0.248 grams $Na_2S_2O_3$ in 1 liter of water; 1 c.c. sodium sulphate solution indicates 0.055 c.c. oxygen) with the addition of a starch solution. The starch solution is prepared in the following manner: One part of starch is thoroughly dissolved in a small quantity of cold water; add 100 parts of boiling water; it is then allowed to settle or is filtered.

2. Dry Matter or Evaporation Residue

Two hundred and fifty cubic centimeters of water is placed in a clean, dried[1] and previously weighed dish, and evaporated over a hot water bath. This is dried for two hours at 110° C. and then weighed. The increased weight of the dish represents the evaporation residue. Calcium carbonate gives a granular residue, gypsum a fibrous, shiny residue, organic substances and iron combinations a dark residue.

3. Organic Matter

(Oxygen Consumption During Oxidation)

The determination of organic substances from the loss of ignition of the dry matter, ordinarily a very common procedure, finds little application in water analysis. As a rule the organic substances are not ascertained as such, but by titrating with postassium permanganate in acid solution the quantity of oxygen consumed by the organic substances during oxidation is determined. It is impossible to estimate the contents of organic substances in water from the amount of oxygen used during oxidation, as the various organic substances that occur in water consume different amounts of oxygen according to their composition. Consequently we are limited in stating the amount of potassium permanganate solution, that is to say the amount of liberated oxygen, in milligrams to 1 liter of water.

Method of Test: Heat for ten minutes at boiling point in a 300 c.c. flask under a watch-glass cover 100 c.c. of freshly distilled water, 5 c.c. of a 25 per cent solution of sulphuric acid and 5 c.c. potassium permanganate solution (0.33 gm. $KMNO_4$ in 1 liter of water). To this add 1/100 N[1] solution of oxalic acid (0.63 crystalized oxalic acid in 1 liter; keeps only about 2 weeks) until it just begins to decolorize. After cooling add to this water now freed from oxidizable substances 8 c.c. permanganate solution; cover with watch glass and again heat exactly 10 minutes; then add 10 c.c. oxalic acid solution, and titrate after complete decoloration and clarification with potassium permanganate until color is pink. After the titer of the variable permanganate solution is determined, empty the flask, add 100 c.c. of the water to be tested, 5 c.c. sulphuric acid and 8 c.c. permanganate solution and proceed as before. If after boiling with the permanganate solution the liquid no longer appears definitely red the test must be repeated with an increased amount of permanganate, or after diluting with distilled water, the water to be tested.

Example of calculation:

100 c.c. of the water to be tested + 10 c.c. oxalic acid consumes 13.75 c.c. permanganate.

100 c.c. distilled water + 10 c.c. oxalic acid consumes 10.55 c.c. permanganate.

100 c.c. of the water to be tested alone consumes 3.20 c.c. permanganate.

10.55 c.c. permanganate solution represents 10 c.c. 1/100 N oxalic acid.

3.20 c.c. permanganate solution represents $\frac{10 \times 3.2 \text{ c.c.}}{10.55}$ 1/100 N oxalic acid.

This equals 3.033 c.c. 1/100 N oxalic acid, and this equals 3.033 c.c. 1/100 potassium permanganate solution[1]. One c.c. 1/100 N potassium permanganate solution equals 0.3163 mg. $KMNO_4$ or 0.08 mg. oxygen. For 1 liter of tested

[1] Drying for the determination of evaporation residues is accomplished by heating for two hours at 110° C. in a hot-air oven. Cooling should be done in an air-tight container (desiccator), which contains some agent which absorbs moisture (H_2SO_4 or anhydrous $CaCl_2$). Weighing is done on a chemical scale which permits the reading of milligrams.

[1] Cf. note on page 32.

water $0.3163 \times 3.033 \times 10 = 9.59$ mg. $KMNO_4$ or $0.08 \times 3.033 \times 10 = 2.43$ mg. oxygen is consumed.

Organic substances, as is well known, may be of different origins. They are most serious when they originate directly from animal and human excretions, as, for example, when feces and urine find their way from toilets, manure piles, etc., into drinking water.

To test for animal waste material we extract with alcohol the evaporation residue obtained from 1 to 2 liters of water, evaporate the alcohol and moisten the residue with caustic potash solution. If an odor of feces results it points toward the presence of animal excreta.

If a sediment is present in the water it should be microscopically examined (cf. page 91).

4. Ammonia (Ammonium Salts)

Ammonia, as well as nitrous acid, is generally formed by the decomposition of proteins and their decomposition products. Less frequently they arise from old humus deposits, in which case they have no connection with waste materials (sewage). Occasionally they seem to originate from the reduction of nitric acid in the presence of ferrosoferic oxid compounds. Under similar conditions hydrogen sulphid is formed in strata of earth containing gypsum. In such rare

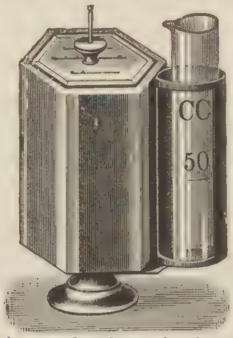


Fig. 30. Colorimeter for determination of ammonia.

cases hydrogen sulphid, ammonia and nitrous acid do not indicate a recent pollution of the soil or water. One is usually content with the qualitative proof, and an estimation of the color development resulting from the following reaction will suffice:

Procedure: Cloudy samples of water should be cleared by adding 1 c.c. of a 2 per cent aluminum sulphate solution to 100 c.c. of water. Hard water (18°) and water rich in iron must first be treated as follows: To every 100 c.c. add 0.5 c.c. of 33 per cent caustic soda solution and 1 c.c. sodium carbonate solution (2.7:5; free from ammonia!); after allowing to settle the clear water should be poured off and then used for the test, which is carried out as follows:

Into a colorless glass cylinder rinsed out with the test water and held over a white background pour 50 c.c. of the water to be tested; then add 1 to 2 c.c. of Nessler's reagent. The amount of ammonia contained in the water is determined by the pale yellow or reddish brown coloration or even by a reddish brown precipitate. For a quantitative estimation compare the hue of the tested water with the hues of temporarily prepared solutions of known ammonium content (0.005; 0.025; 0.05 mg. NH_3 to 100 water) or with the fixed color scale

which Kœnig has produced for the colorimetric determination of ammonia, nitrous acid and ferric oxid (Fig. 30). The six color hues express an ammonium content of 0.05, 0.10, 0.25, 0.50, 0.75 and 1.00 mg.

Nessler's reagent is prepared as follows: Fifty grams of potassium iodid is dissolved in 50 c.c. of hot distilled water, then treated with a concentrated solution of mercuric chlorid until the resulting red precipitate no longer dissolves (about 20 to 25 gm. mercuric chlorid); then filter the mixture. To the filtrate add a solution of 150 gm. potassium hydroxid in 300 c.c. of water; fill up to one liter; add about another 5 c.c. mercuric chlorid solution; allow the precipitate to settle, and carefully pour off the clear supernatant liquid. The liquid must be stored in well sealed bottles.

5. Nitrous Acid (HNO_2 or N_2O_3)

Fill a reagent flask three-quarters full with the water to be tested; add 3 to 4 drops of concentrated sulphuric acid and 5 to 10 drops metaphenylenediamino solution. In the presence of but 0.5 mg. nitrous acid in 1 liter a golden yellow to brown or reddish color appears. With water tests of yellowish hue notice should be taken whether the coloration is intensified by the reagent.

Preparation of the metaphenylenediamino solution: Dissolve 1 gm. pure metaphenylenediamino with the addition of 3 c.c. concentrated sulphuric acid in 150 c.c. distilled water, then bring the volume up to 200 c.c. with more distilled water. This must be stored in a brown bottle. Browned solutions can be decolorized by heating with animal charcoal.

Quantitative estimation is accomplished by colorimetric comparison as with the determination of ammonia.

6. Nitric Acid (HNO_3, N_2O_5)

For nitric acid the qualitative determination generally does not suffice but the amount must be ascertained quantitatively.

Qualitative determination: To 2 c.c. of a solution of a sulphuric acid solution of diphenylamin in a clean bowl add drop by drop about 0.5 c.c. of the water to be tested. In the presence of nitric acid blue lines or rays will appear. The diphenylamin solution is prepared by dissolving 20 gm. diphenylamin in 20 c.c. 25 per cent sulphuric acid and filling up to 100 c.c. with pure concentrated sulphuric acid.

Quantitative determination: Busch's method offers a fairly definite test of whether a water is objectionable because of too great nitrate content. It is as follows: Acidify 5 to 6 c.c. of water with a drop of diluted sulphuric acid and then add 6 to 8 drops of a 10 per cent solution of diphenylendanilodihydrotriazol (Nitron, Merck) in 5 per cent acetic acid. If white crystals of nitron nitrate form within two minutes, then the liquid contains over 100 mg. nitric acid. If, however, no reaction appears within an hour, then less than 25 mg. of nitric acid is present in one liter of water.

7. Hardness (Lime and Magnesium Salts)

The hardness of water depends on its content of salts of lime and magnesium. Soft water contains about 8 degrees of hardness, medium hard 8 to 12, hard 12 to 30, and very hard water over 30. Good tap water should not have more than 12 degrees. Water is softened by boiling. The existing bicarbonates of lime and magnesium salts are split into carbonic acid and almost insoluble simple carbonates of salts. The salts separated by boiling constitute the temporary, transient or carbonate hardness. The dissolved remaining lime and magnesium salts (sulphate, nitrate, chlorid) constitute the

enduring, permanent, noncarbonate or mineral acid hardness. Both together constitute the total hardness. The hardness can be determined from the lime and magnesium content by changing the magnesium value to the lime value by multiplying the magnesium (MgO) by 1.4. This added to the lime (calcium oxid) content (CaO), and estimating that 1 mg. in 100 c.c. of water (or 1:100,000) represents 1 (German) degree of hardness.[1]

The simple method of determining hardness with soap solution is ordinarly used for hygienic purposes. Lime and magnesium salts convert soap (sebacic alkali) into insoluble sebacic lime and magnesium as well as into the corresponding alkali salts. The end of the reaction, that is, the surplus of soap solution, is recognized by the foam which is produced by shaking and which remains.

Determination of Total Hardness: First of all the soap solution[2] is standardized with a gypsum solution[3]; 45 c.c. of soap solution should exactly correspond to 100 c.c. of gypsum solution, that is, 12 degrees of hardness.

Procedure: 100 c.c. of the water to be examined is placed in a 200 c.c. flask having a stopper. Allow the soap solution to flow into this at first abundantly, then only 1 or ½ c.c., and finally drop by drop until after vigorous shaking a thick, light foam appears which remains unchanged for at least five minutes. The consumption of soap solution should not exceed 45 c.c. and should remain near that amount. Water which contains more than 12 degrees of hardness should be diluted accordingly with distilled water. The number of cubic centimeters of consumed soap solution shows according to the following table the degree of hardness of the tested water. If the original water was at first diluted the discovered degree of hardness should be multiplied by the dilution factor.

Determination of Permanent Hardness: Boil 500 c.c. of water in a 1 liter flask for half an hour, frequently replacing the evaporated water with distilled water. After cooling in a 500 c.c. volumetric flask fill up with distilled water, mix thoroughly and filter through a dry filter. The filtrate is used as above when determining hardness.

Soap Solution c.c.	Degree of Hardness	Soap Solution c.c.	Degree of Hardness	Soap Solution c.c.	Degree of Hardness
3.4	0.5	18.9	4.5	33.3	8.5
5.4	1.0	20.8	5.0	35.0	9.0
7.4	1.5	22.6	5.5	36.7	9.5
9.4	2.0	24.4	6.0	38.4	10.0
11.3	2.5	26.2	6.5	40.1	10.5
13.2	3.0	28.0	7.0	41.8	11.0
15.1	3.5	29.8	7.5	43.4	11.5
17.0	4.0	31.6	8.0	45.0	12.0

[1]In France degrees of hardness mean units of calcium carbonate (in Germany calcium oxid) in 100,000 parts of water. The French degrees of hardness can be transposed into German by multiplying by 0.56.

[2]Soap solution: Soften 150 gm. lead plaster on a hot water bath, triturate with potassium carbonate into a mass of uniform consistency, treat with alcohol, and then filter the solution, distill off the alcohol and dry the remaining soap on a hot water bath. Of this soap 20 gm. is dissolved in 1,000 parts of 56 per cent alcohol.

[3]Gypsum solution: From a gypsum solution saturated at 20° C. take 142 c.c. and fill this up to 1 liter with distilled water. The resulting solution contains 12 degrees of hardness. In place of the gypsum solution a solution of 0.5236 gm. of pure, dry, crystallized barium chlorid in 1 liter of distilled water may be used.

8. Chlorids

The quantitative determination may be made by weight or volumetric analysis or by the colorimetric method.

The chlorid content may be approximately ascertained most easily by the colorimetric method in the following manner: 10 c.c. of the water is mixed with 2 drops of pure nitric acid and 5 drops of a 5 per cent solution of silver nitrate. The chlorid content is determined by the strength of the whitish turbidity or even of a precipitate. If there is not more than 20 to 30 mg. of chlorids (the usual quantity in clear water) in 1 liter of water, only a slight turbidity appears. If in doubt prepare a control fluid (0.0329 $NaCl = 0.02$ Cl: 1000 H_2O; or 0.0493 $NaCl = 0.03$ Cl; 1000 H_2O), and proceed with this in the same manner as in the chlorid determination and compare the resulting turbidities.

9. Sulphuric Acid

After adding some hydrochloric acid to 200 c.c. of water, precipitate the sulphuric acid at boiling temperature with barium chloride solution, filter the resulting barium sulphate off, rinse, dry, burn and weigh it. The amount of barium sulphate found multiplied by 0.343 gives the amount of sulphuric acid (SO_3) that was present.

10. Phosphoric Acid

The phosphoric acid that may be present in the water never comes from the soil but always from sewage (liquid manure pits, manure and dung heaps). About 100 c.c. of the water to be tested is acidified with nitric acid and then evaporated dry. The residue is then dissolved in diluted nitric acid, filtered, and the filtrate treated with ammonium molybdate solution. A yellow precipitate will appear within 24 hours if phosphoric acid is present.

11. Iron

If iron is present in any great quantity it can be detected by acidifying the water with hydrochloric acid and then treating it with several drops of potassium ferrocyanid solution. The appearance of a blue color denotes the presence of iron.

For a quantitative colorimetric determination evaporate 500 c.c. of the water to 100 c.c., pour it into a colorless glass cylinder and add 5 c.c. ammonium thiocyanate solution (7.5 gm. to 1,000) and 1 c.c. of hydrochloric acid diluted 1 to 3. The color intensity which appears is then to be compared with Koenig's apparatus (Fig. 30), which is very suitable, or with the color tones that are obtained with the following four tests: Prepare four graduated cylinders; in the first one place 1 c.c., in the second 3 c.c., in the third 5 c.c. and in the fourth 7 c.c. of ferric oxid solution; then fill each up to 100 c.c. with distilled water; then to each add 5 c.c. ammonium thiocyanate solution and 1 c.c. diluted hydrochloric acid.

The oxide solution is prepared by dissolving 0.4306 gm. of pure, crystalized ferric oxid ammonium sulphate in a little hydrochloric acid in 1 liter of water. One c.c. of this solution represents 0.00005 gm. iron or 0.00035 gm. ferric oxid.

12. Lead

Mix 100 c.c. of freshly drawn clear water with 2 to 3 drops of a 10 per cent potassium cyanid solution. After 2 or 3 minutes add to this 10 c.c. of a solution of 100 gm. of ammonium chlorid in 5 per cent ammonia and then bring the total volume to 500 c.c. Lead produces a brown discoloration.

For colorimetric determination, add to 100 c.c. distilled water equal amounts of the above-mentioned reagents and drop enough of a solution of 0.160 gm. triturated lead nitrate dried at 100° C. into 1,000 c.c. of water until the same color appears as in the foregoing test. One c.c. of lead nitrate solution represents a lead content of 0.1 mg. lead in 1 liter of water.

To determine the *lead solvent effect of any water*—which must be done immediately after drawing off the water—fill a glass cylinder having a ground glass stopper entirely full of water without admitting any air. Two halves of a lead pipe previously cleaned with diluted nitric acid, rinsed with distilled water, dried, and polished with a clean cloth, are carefully lowered into the water cylinder. The cylinder is then filled to the top with water (without admitting air) and sealed. After 24 hours the halves of the lead pipe are taken out after lifting them up and down in the water several times. The water is then tested for lead.

13. Copper

For a qualitative test add to 100 c.c. of water, without acidifying, 2 to 3 drops of fresh 1 per cent potassium ferrocyanid solution, and compare the color with pure water. In the presence of 0.5 mg. of copper a reddish color will appear, which, upon the addition of 2 to 3 drops of potassium cyanide solution, will turn greenish yellow.

Very soft water should first be treated with 0.2 per cent of potassium or sodium carbonate.

For a quantitative test carry out the same test as above with 100 c.c. of distilled water to which enough copper sulphate solution (0.3925 gm. crystallized salt to 1 liter; 1 c.c. equals 0.1 mg. copper) is added to produce a similar color to that mentioned for the foregoing test. Upon the addition of potassium cyanide an equally strong greenish yellow coloration must occur in both tests.

14. Zinc

Proving the presence of zinc is more difficult. In regard to this consult Beythien, Hartwich and Klimmer, "*Handbuch der Nahrungsmitteluntersuchung,*" vol. i, p. 880, Leipzig, 1913, Tauchnitz.

Judging Water After Chemical Analysis

The results of the chemical examination are not generally suited to allowing direct conclusions to be drawn concerning the sanitary condition of the water (see pages 76-83). The exceptions to this are lead, very seldom copper and arsenic, and perhaps in exceptional cases iron, nitric acid and deficiency in lime (page 77).

However, the results of the chemical examination are valuable because they invariably indicate a pollution of the water, even through human and animal waste matter. Water pollution is denoted by a simultaneous high content of organic substances, nitrates, chlorids, phosphates and sulphates when occurring simultaneously with ammonia, especially when neighboring spring and well water in the same stratum and under the same natural soil conditions show no similar high content in the constituents mentioned. The test for animal waste matter (page 86) may also be included. On the other hand, a partial high content (of the water) in organic substances or chlorids, nitrates or sulphates may originate from natural layers of the ground (see page 71). When judging a water the quality and condition of the natural ground water should be taken into consideration as much

as possible. The average content of drinking water in organic substances, ammonia, nitrites and nitrates, chlorids and sulphates must not esentially exceed the average content of the natural, nonpolluted water of the same locality and same formation; otherwise pollution exists.

If it has been proved by a chemical analysis that pollution of the water exists, then it is possible that with the pollution a contamination with living pathogenic organisms has also occurred. But on the other hand one is not justified in immediately presuming that a contamination with living pathogenic organisms exists because of chemical pollution, nor in deducing a parallelism between the two. The ways in which the previously mentioned substances on the one hand and the living pathogenic organisms on the other enter the water may be different and independent of one another (page 71). Organic substances, ammonia, nitrites, nitrates and chlorids very often gradually pass through the supersaturated soil into the ground water. The pathogenic organisms can not enter this way; they get into the water only through seepage at the place from which the water is drawn.

IV. Microscopic and Bacteriological Examination

When water is to be *examined microscopically* it is either centrifuged or allowed to settle (Fig. 31) 12 to 14 hours and the sediment examined. This is most easily done by drawing up some of the sedi-

Fig. 31. Sedimentation glass.

Fig. 32. Animal organisms. *a-c*, from well water in which putrefaction is occurring without extraneous pollution. *a, Paramaecium aurelia* (x 150); *b, P. putrinum* (x 300); *c, Oxytricha pelionella* (x 200); *d, Chilodon cucullus* (x 200); *e, Vorticella microstoma* (x 200); *f, Planaria gonocephala* from filthy water.

ment with a sterile pipette and then making a cover-glass preparation.

With the aid of the microscope one can find the following in the sediment:

A. *Inorganic and inamimate organic substances:* Quartz and other osil particles, iron precipitates (brown amorphous masses, soluble in acids), remains of plants, threads of wool, cotton and linen, starch granules (compare Fig. 10 b—g), fecal remnants, e. g., small particles of meat which usually appear as yellow lumps through the imbibition of bile salts, etc.

B. *Animal organisms*:

I. Protozoa.

1. Rhizopods: *Amœba porrecta, A. diffluens, A. proteus, Petalopus diffluens, Podostoma filigarum, Actinophrys sol, Acanthocystis, Clathrulina.*
2. Infusoria: *Paramecium aurelia* (Fig. 32a), *P. putrinum* (b), *Oxytricha pelionella* (c), *Epistylis, Chilodon* (d), *Monas, Mallomonas, Euglenia vorticella* (e), etc.

II. Vermes.

1. Turbellaria: *Monocelis, Planaria* (f).
2. Nematodes: *Anguillula fluviatilis.*
3. Rotifers: *Rotifer vulgaris.*

III. Arthropods, articulated animals (can generally be recognized macroscopically).

1. Crustacea: *Branchipus, Daphnia pulex, Cyclops, Cypris,* etc.
2. Arachnids: Tardigrads, water mites.
3. Insects: Gnat larvæ.

Detecting the presence of animal parasites is of more importance; for example, eggs of the following intestinal worms: *Enterobius vermicularis, Trichuris, Dioctophyme renale, Setaria equina, Habronema microstoma, H. megastoma, Strongylus equinus, Æsophagostomum dentatum, Hæmonchus contortus, Metastrongylus apri, Dictyocaulus viviparus, D. filaria, Tænia achinococcus, T. solium, T. saginata, Bothriocephalus, Ancylostoma duodenale,* etc., as well as *Distomum* (Fig. 33).

C. *Vegetable organisms:*

I. Cyanophycea: *Hypheothrix coriacea, Oscillaria viridis, Aphanicapsa, Chroococcus.*

II. Diatomes, gravel algæ: *Navicula* (Fig. 34a, b). *Fragilaria, Stauroncis, Otontidium, Synedra* (c), *Diatoma, Tabellaria, Surirella, Melosira,* etc.

III. Protococcoids: *Scenedesmus, Protococcus, Stichococcus, Palmella.*

IV. Confervacea: *Conferva* (d), *Oedogonium.*

V. Saprolegniacea and other eumycetes on decaying vegetable and animal remains.

VI. Schizomycetes, bacteria: sulphur bacteria, *Beggiatoa;* iron bacteria, *Crenothrix polyspora,* (Figs. 27 to 29, cocci, bacilli and spirilla.

Bacteria require special discussion. One c.c. of pure tap water and spring water contains about 2-50 bacteria, pure well water 100-200-500, filtered river water 50-200, nonfiltered water of rivers that are kept clean 6,000-20,000, polluted well water as many as 100,000, and canal water and water of badly polluted rivers 2 to 40 millions of bacteria.

Bacteria which occur in water are usually harmless putrefactive bacteria and belong to very many different species. Pathogenic bacteria seldom appear, and if they once gain entrance into the water

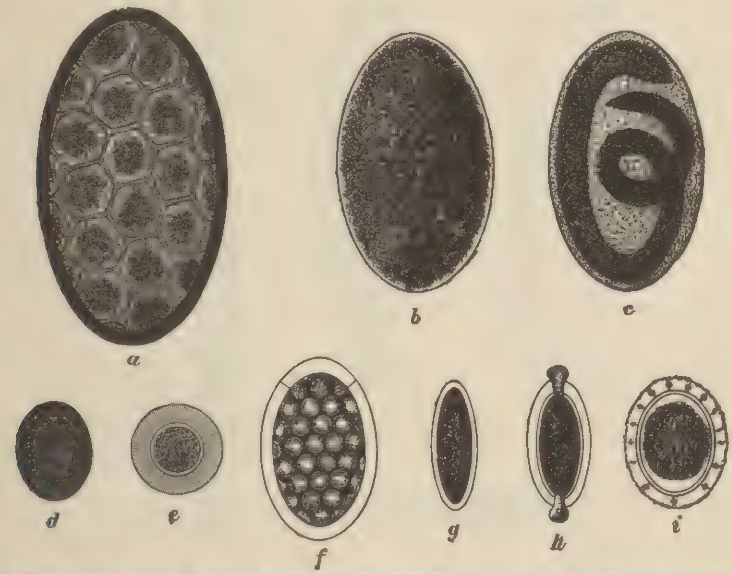


Fig. 33. Eggs from several intestinal worms (enlarged x 30). *a*, from large liver fluke (*Fasciola hepatica* s. *Distomum hepaticum*); *b*, from lungworm (*Dictyocaulus filaria*); *c*, egg from the same with finished embryo; *d*, from the small liver fluke (*Distomum lanceolatum*); *e*, from tapeworm (*Taenia solium*); *f*, *Bothriocephalus*; *g*, *Oxyuris curvula*; *h*, *Trichuris crenatus*; *i*, *Ascaris marginata*.

they usually, with the exception of typhoid fever and human cholera, do not multiply but remain viable for a short or long period of time; this especially applies to their spores (anthrax spores).

Bacteria gain entrance into water in various ways. They may be carried from the surface soil by means of precipitants and through industrial pollution (e. g., spores from tanneries) into the water (brooks, rivers and open conduits). They may also gain entrance into the well water through defective well structure (damage in the covering and walls, cracks between the pervious wall and adjoining ground, etc.). In deeper strata such means of polluting influxes seldom occur (fissures and cracks in dry loamy soil, crevices in rocky soil). In other instances germs may get into the water during the

construction of the well, the inclosing of a spring, during the construction or improvement of a conduit, through transporting particles of surface soil, through the materials and supplies used, and by workmen, etc.

The simple microscopic examination is not sufficient to determine the number and kinds of bacteria in the water. Several different kinds of processes, referred to as *bacteriological examinations,* are employed.

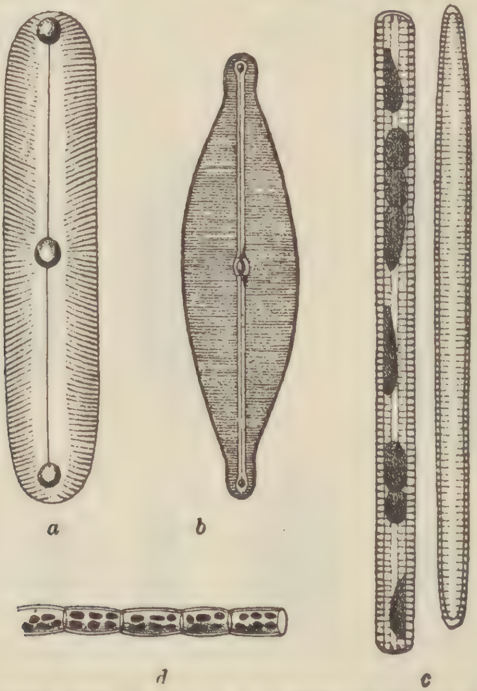


Fig. 34. Algae. *a, Navicula viridis* (x 350); *b, N. cuspidata* (x 900); *c, Synedra ulna* (x 300); *d, Conferva bombycina* (x 300).

To determine the number of bacteria present in the water there are added to liquefied nitrient medium, which solidifies again at room temperature, measured quantities (0.05, 0.1, 0.5 and 1 c.c.) of the freshly drawn undiluted water to be tested (see p. 67), or, if the water is presumably high in germ content, it is diluted (10-1,000 times) with sterilized water before being added to the medium. This is at once thoroughly mixed and allowed to solidify in a sterile Petri dish. After the bacterial colonies have developed they are counted. This number is taken to indicate the number of the bacteria existing in the water and is calculated to 1 c.c. of undiluted water.

These are the fundamental features of the method of determining the presence of germs in water. Unfortunately there are left to the investigator a great number of important details in the execution of the tests (kind of nutrient medium, measuring and admixture of the different quantities of water,

duration and the temperature of the incubation, manner of counting the colonies, etc.) This has the great disadvantage that the results made according to the different methods can not be compared with one another[1].

The following are suggestions advanced by Hesse and Nieder:

1. As a nutrient medium filtered nutrient agar is used. It is composed of 10 gm. agar, 10 gm. peptone, 5 gm. sodium chlorid and 1 liter of distilled water. This should, if possible, be drawn off into test tubes which give off no chemical substances, especially no alkali, during the sterilization and storing.
2. The water to be tested should be measured with a sterilized 1 c.c. pipette; smaller quantities with a sterilized graduated dropping bottle, and still smaller quantities with a gaged platinum loop if one does not prefer to dilute the water to be tested with sterilized (testing) water. The diluting must be done so that 200 to 2,000 colonies will develop on one dish. In case the germ content is unknown a series of about five dilutions (1:10, 1:100, 1:1,000, 1:10,000, 1:100,000) should be made. The measured water should be placed directly into the empty Petri dish (instead of as usual into the test tube), mixed thoroughly with the nutrient agar, which is added in a liquefied condition, and the mixture then cooled to 37-38° C.
3. The bacteria in the poured plates should be grown at room temperature (18-25° C.) for 21 days. (This period may be shortened to 10 days, but in that case about one-tenth must be added to the number of bacteria found.)
4. Counting the colonies should preferably be done under the microscope[1]. The count may be made, however, with the aid of a magnifying glass or even with the naked eye, either of which methods gives results that are usually useful.

Great importance has been repeatedly attributed to the detection of *Bacillus coli* in drinking water (Page 96). Fromme performs the *B. coli* test in the following manner:

1. One c.c. of water is inoculated into 1 per cent glucose bouillon in order to make a fermentation test.
2. Nine parts of water are mixed with 1 part dextrose-peptone-sodium chlorid solution (10:10:5). If gas forms after 24 hours at 37° C. then Endo plates are inoculated from which *B. coli* colonies are isolated and grown on agar in pure culture. *B. coli* is recognized by its growth on agar, fermentation of dextrose, coagulation of milk, reduction of neutral red and characteristic growth on Endo's agar.

Most bacteria found in water are harmless putrefactive organisms, but pathogenic bacteria can also occur in water (p. 77). Extensive research is necessary in order to prove positively their presence. For this purpose special methods are used at times, as in the case of the typhoid bacillus and the causative agent of asiatic cholera; in other cases animal experiments are used (anthrax bacillus, fowl cholera bacillus, etc.). It is beyond the scope of this book to discuss in further detail these methods of research, for the execution of which a well-equipped bacteriological laboratory is necessary. Any standard text-book on bacteriology will give information on this subject.

Judging Drinking Water According to Microscopic and Bacteriological Findings.

Substances which are microscopically recognizable in the sediment, especially those of organic nature, are doubtful. If they originate

[1]In the United States uniform methods are followed, as outlined in "Standard Methods" by the United States Public Health Service. This applies for both chemical and bacteriological water analysis. (*Translator's note.*)

[1]For directions for counting with the microscope see Busch, Zeitschr. f. Untersuchung der Nahrungs und Genussmittel, 1905, vol. 9, p. 464.

from vegetable decomposition and contain *Crenothrix* and other fungus filaments, infusoria and diatomes, they are not injurious to health on that account. If on the other hand, a pollution with animal waste matter can be definitely established (toward which the results of chemical examinations indicate many bacteria, infusoria, radiolaria, fragments of feces or even eggs of maw and tapeworms), then such water is very suspicious and may in special instances become directly harmful to health.

It is difficult to judge the condition of water on the results of bacteriological investigation. It is seldom that direct proof of the presence of pathogenic organisms in the water is obtainable, even when the water has been causatively concerned in the spreading of a disease. The recognition of the existing pathogenic microorganisms, which are always in a decided minority, among the saprophytic ones is very difficult; furthermore, it often occurs that the pathogenic bacteria are no longer present in the water at the time of the investigation.

The germ content of the water affords an insight into a probable previous contamination; as to the danger of infection it permits of only limited conclusions. Waters with a low germ content (less than 20 germs in 1 c.c.) offer no danger of infection. If a moderately large number of bacteria (20 to 200 in 1 c.c.) are found in the water, then the danger of infection is not definitely excluded, even though it is not likely. Waters rich in germs (200 to 5,000 and over) must be judged differently, according to the conditions existing at the time of the examination. In the case of well water they may come from the well construction (masonry) and consist mainly of water bacteria; or, for example, they may get into the well from the eaves of a roof. In such cases they do not demand consideration. However, a totally different conclusion would be drawn if influxes of a suspicious nature came under consideration.

The kinds of bacteria, other than pathogenic, do not afford a basis for concluding definitely that danger of infection exists. *Bacillus coli,* which is habitually present in the intestines and in feces, also occurs otherwise widely distributed in nature. Its presence in water is frequently not considered as evidence of a fecal pollution. On the other hand, Fromme has proved that the discovery of *B. coli* in drinking water usually can be traced to pollution. The *B. coli test* (page 95) is at times a more exact means of detecting pollution than making a bacterial count. The finding of saprophytic bacteria in great variety of species (which usually can not be distinguished from the ordinary water bacteria and germs originating in the masonry of the well) creates suspicion of the existence of greater polluting influxes. The increased appearance of anaerobic bacteria denotes putrefactive processes in the water. In non-putrescent water the anaerobic bacteria bear a relation of 1-5:1,000 to the aerobic; in putrescent water 1:1.

A single investigation frequently will allow no definite conclusions to be reached in this respect, continuous tests generally being necessary.

D. The Water Supply and Water Improvement

I. The Water Supply

The water supply in rural districts is even today to a great extent separate for each individual household. On the other hand, in larger communities the water supply is almost universally centralized. Such a central water supply serves first of all to provide drinking water for the people. It is usually laid out appropriately and is controlled by health authorities. Water which is fit for human consumption could hardly ever be considered objectionable from the veterinary standpoint. The conditions relating to the individual farm water supply are very different. Here very important deficiencies often occur. In the following pages special consideration has therefore been given to this type of water supply.

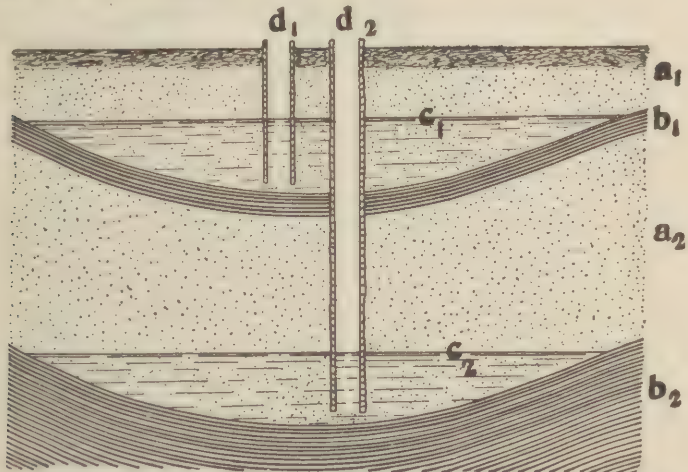


Fig. 35. Shallow and deep well. *a*, Superficial pervious layer; a_2, deep pervious layer; *b*, superficial impervious layer; b_2, deep impervious layer; *c*, high ground water; c_2, deep ground water; *d*, shallow well; d_2, deep well.

In the case of the local farm water supply the water is taken from the ground water (wells), springs, open bodies of water or from rain water.

The *ground water* is made accessible by means of dug or pit wells, driven wells or artesian wells. Open draw wells should be rejected because of the danger of contamination. Deep wells that obtain their water from deeper strata are preferable to the shallow wells, as the deeper strata are purer and contain fewer germs and also have a more abundant supply of water during the summer (Fig. 35).

The *dug wells* (pit wells) (Figs. 36 and 37) are usually located near

the houses, and are therefore easily polluted if suitable preventive measures are not taken. In constructing such a well attention must first of all be given to the following items:

1. The position of the manure pile, privy, cesspool, waste water ditches, etc.; if possible not less than 10 yards distant from these.

2. The depth. The well should go through the stratum which is rich in bacteria and reach into the deeper soil containing fewer bac-

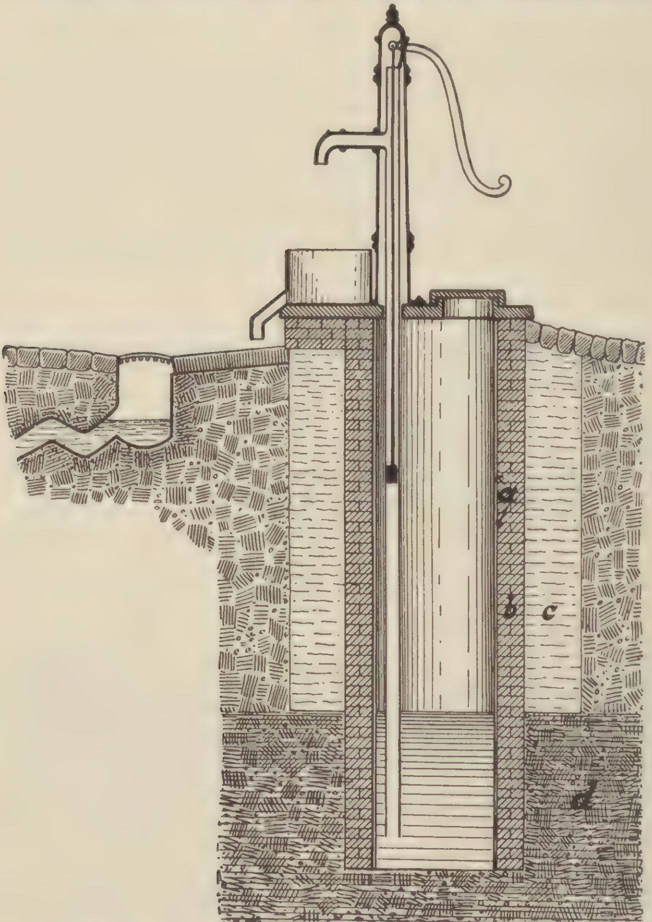


Fig. 36. Good basin well. *a*, Cement lining; *b*, masonry; *c*, loam strip; *d*, ground water.

teria. In sandy subsoil the well should be at least 3 to 4 yards deep; in loose gravel soil at least 6 to 8 yards, and should reach 1 or 2 yards below the ground-water level.

3. An absolutely impervious wall should be constructed so as to allow the water to enter only from below, not from the sides. A wooden lining should never be used, as it is pervious and subject to decay. The wall should be built of stones set in water-tight cement.

As the masonry often enough develops crevices in time, and the cement plaster crumbles off and allows an influx from the sides, it is advisable to prevent this by filling in a space between the wall of the well and the surrounding soil with heavy layer (half a yard to one yard thick) of firmly pounded loam or clay.

4. The cover should be water-tight and arched, on the wall of the well should extend about 10 inches above the ground and then be covered so that surface water can not enter.

5. The pump usually stands directly over the well pit. It is more expedient, however, to place the pump 2 or 3 yards to the side and to connect it with the well pit by means of piping. In this way there is less possibility of contamination of the well from above and from the waste water from the pump. However, such a pipe is possible only when the ground water is not lower than 8 yards. The water pipe and the pump should be of iron; wooden ones are not to be considered.

6. The surface soil should slope gently away from the well cover or casing.

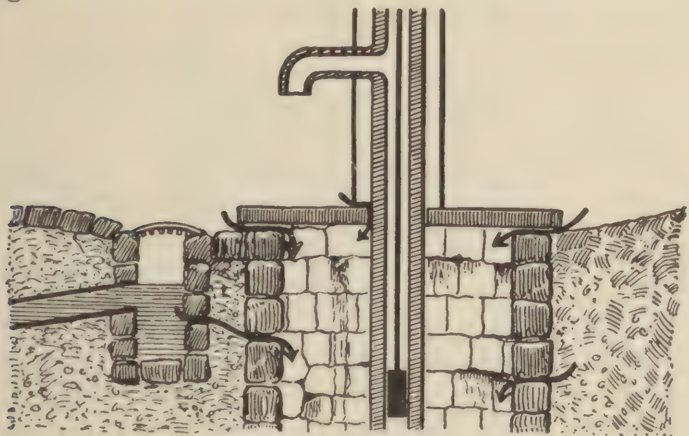


Fig. 37. Poor basin well.

7. The waste water from the well should be carried away by an impervious gutter. Defective pit wells may be improved by rebuilding the wall or making the casing tight from the outside with cement plaster and clay packing down to the stratum that does not contain bacteria, or the pit of the well may be filled with sand, which acts as a filter and converts the iron pump pipe into a driven well.

It is difficult to disinfect a pit well. Methods of doing this are to pour in caustic lime; to inject steam, e. g., from a portable boiler, until the water reaches a temperature of 90° C. (194° F.); through the action of 0.1 per cent sulphuric acid, which does not affect lead and iron pipes, and by injecting ozone.

Driven wells (Fig. 38) have the advantage over pit wells in being cheaper and more germ-proof, but have the disadvantage of giving a

smaller yield. There is no reservoir, and the inflow of the water to the well takes place very slowly because the ground water flows with such slight velocity. As shown in Fig. 38, the driven well consists of an iron pipe driven or bored (a) into the ground. The lower section

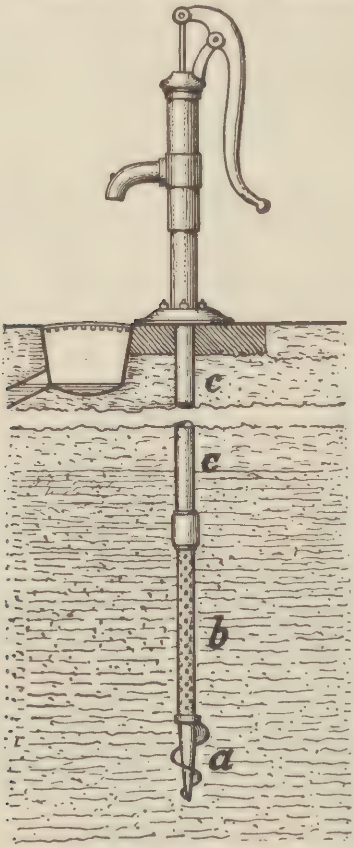


Fig. 38. Driven well. Water enters at *b*.

of the pipe is perforated (b) and has an interior diameter of 3-6.5 cm. (1¼ to 2¾ inches). The perforated portion is surrounded by a fine tinned wire gauze. The pump is attached to the upper part of the pipe. A steel tip or screw at the lower end makes it possible to drive the pipe into the ground without clogging it. The surrounding ground acts as a solid casing for the pipe so that impurities are excluded. Before using the new driven well the water should be pumped out for two or three days until all loose sand has been removed from the well. These wells are recommended especially for sandy or coarsely porous soil and wherever the ground water stands high, consequently being impure or questionable, so that the water can be taken from a greater depth, where it is cleaner and less likely

to be infected with germs. Moreover, they have the advantage that they can easily be disinfected. (This may be done by pumping out, by cleansing mechanically by means of special brushes, or by pouring in a 5 per cent mixture of crude carbolic acid and sulphuric acid or injecting steam at 100° C. for hours.)

An *artesian well* (Fig. 39) is one whose water rises above the surface level without the aid of artificial devices and which shows a so-called "piezometric level." The water frequently comes from a great depth (100 to 1,000 yards). Nevertheless a connection with the surface water may exist. The water is usually hygienically pure, yet an artesian well does not offer absolute protection against infection.

In providing a *spring water* supply particular attention should be given to the following:

1. The spring should be protected in such a way that extraneous contamination is impossible.
2. The piping should be entirely closed and made of suitable material.

The simplest manner of protecting a spring is by constructing a walled-in basin of masonry in the cleft rocks from which the spring emanates, with an outlet raised to a suitable height. In this way the surface water is prevented from flowing in from the sides, and soil ingredients from being stirred up and causing turbidity of the water. The water basin should be provided with a suitable overflow and a drain that can be closed, and should also be covered so that impurities from above are excluded; or, still better, the basin should be inclosed so as to form a well or chamber. (See Fig. 40.) The construction should be of weathered stones or cement mortar. Wood should be avoided, as it decays and affords a harbor for bacteria.

The water pipes and conduits should be completely inclosed. Open or poorly covered gutters should be avoided. The material used should be sufficiently resistant to withstand water pressure. And finally, the piping should be placed at least 1.5 meters (5 feet) deep so as not to be affected by the outside temperature, i. e., not to frezee in winter and to supply cool, refreshing water in summer.

Wooden water pipes are still sometimes used in the country, but they are not at all suitable, because of susceptibility to decay, affording breeding places for bacteria and not being water-tight. Cement, clay or iron pipes are the most serviceable. For long conduits of large diameter cast-iron pipe should be used, and for narrower conduits wrought-iron pipe. However, the latter has the disadvantage of easily rusting, whereas cast-iron pipe rusts only when not continually filled with water. To prevent rusting even under such conditions the pipe is lined with asphalt or zinc or dipped into a mixture of tar and linseed oil[1].

[1]In the United States rusting is obviated by the use of galvanized wrought-iron pipe, usually in diameters of 1¼ and 1½ inches.—J. R. M.

For shorter conduits with many bends lead pipe is given the preference. In order to avoid any lead dissolving and causing poisoning, the lead pipe is frequently lined with lead-free tin 0.5 mm. thick.

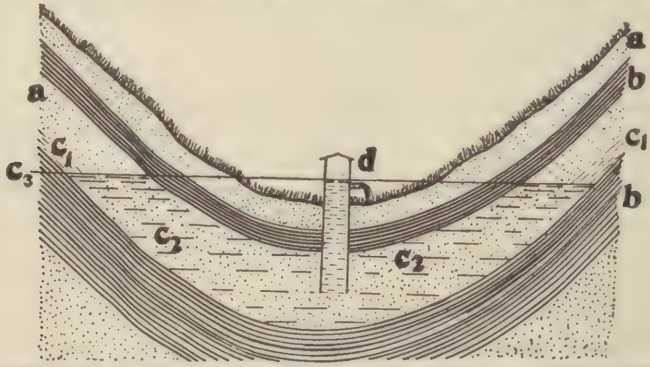


Fig. 39. Artesian well. *a*, Pervious layer; *b*, impervious layer; *c*, influxing ground water; c_2, ground water zone; c_3, ground water level; *d*, artesian well with overflowing water.

Care must be taken that the soldering is well done and that cracks are avoided in the tin pipe, so that no lead goes into solution through electrolysis. In view of the fact that the carbonates prevent a solution of lead, (p. 76) the dangers which exist when lead-dissolv-

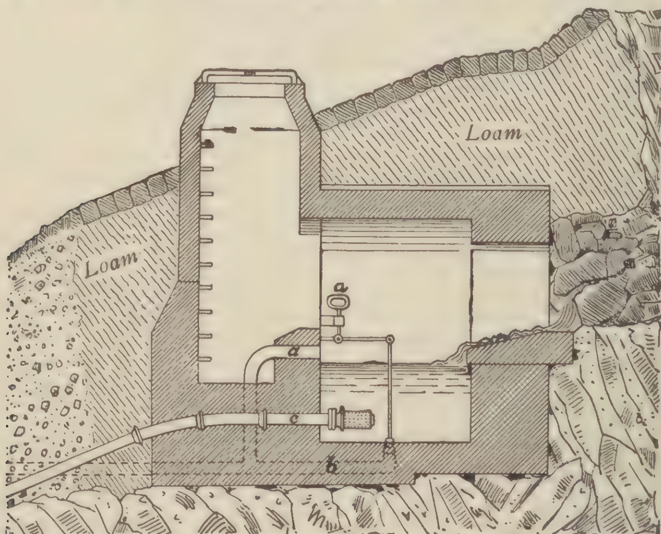


Fig. 40. Appropriate arrangement of a well. *a*, Overflow; *b*, ground drain; *c*, water pipes.

ing waters are conducted through lead pipe are removed by an admixture of carbon dioxid salts with the water. The consumer, that is to say, the owner of animals, can most easily avoid lead poisoning by allowing the soft, aerated water which has stood overnight in the lead pipes to run off unused.

If it is necessary that *rain water* be used as a water supply, it is best to use the water that falls on the roofs of houses. The first part of the rain water, which is more markedly polluted, should be

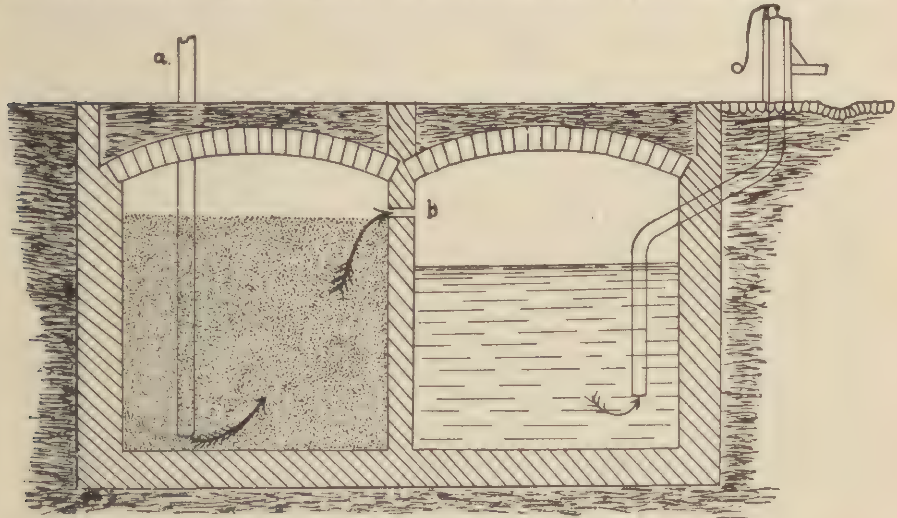


Fig. 41, Cistern. *a*, Rain pipe; *b*, overflow.

allowed to run off unused, and only the cleaner water which follows should be collected. Open containers (barrels, etc.) are not suitable;

Fig. 42. Enclosure of a water hole.

they are too susceptible to contamination. It is best that the water be conducted through a pipe into a water-tight pit or compartment

provided with a sand filter (Fig. 41). The water should first pass through the sand filter, and be cleansed of the particles of impurities; then it should pass through an overflow into an adjoining water-tight cistern which is well covered and from which the water is drawn by means of a pump. Rain water should be treated with some salt before using.

Open bodies of water (brooks, rivers and ponds) should not be used as a source of drinking water without filtration except in sparsely settled forest regions. Open bodies of water and rain water are principally influenced by the outside temperature. Suspicious water should, if possible, be filtered before using (see below).

Small collections of stagnant water (*pools, water-holes*) from a hygienic standpoint are most suspicious. In the stock-raising industry one is at times restricted to such water supplies. It is then advisable that such places be fenced in so that the animals can drink but can not step in nor drop their excrement into the water (Fig. 42).

Greater importance should be given to proper water supplies than is often done.

II. The Improvement of Water

The improvement or purification of the water may seem necessary for various reasons. In case of ground waters which are very rich in iron a removal of the iron may be necessary. Rain water and open bodies of water (water from brooks, rivers and pools) should be freed of suspended matter, especially bacteria and other causative agents of disease, by filtration.

Iron may be removed from well water for many years by surrounding the pit of the well with a layer of quicklime (pyrolignite of lime) and by covering the bottom with a 4-inch layer of the lime and placing over this 8 inches of sand. However, this simple procedure fails with some waters that contain iron. In such cases the water must first be thoroughly aerated, whereby the dissolved bicarbonate of ferrous oxid $Fe(HCO_3)_2$ is converted into insoluble ferric hydroxid $Fe(OH)_3$. Such aeration of the water is accomplished by allowing the water to trickle down from a sprinkler over a porous substance. The simplest construction for such a removal of iron consists of a barrel with the following arrangement built in: A few inches above the bottom of the barrel is fastened a sheet of zinc 1 mm. thick, which has many perforations. On this sheet a 12-inch layer of coarse sand (1 mm. grain size) is placed. Below the sheet of zinc a drain cock is adjusted, which is protected against the entrance of sand by brass wire gauze. The filter should stand empty overnight with drain cock open. The sand should be washed every 2 to 4 months. A second barrel in which the filtered water is collected should be placed under the filter barrel.

In larger appliances for the removal of iron the water flows in a spray over a layer of small pieces of coke or gravel and then is generally filtered through a layer of sand for the complete removal of the flakes of iron.

Waters rich in iron often contain hydrogen sulphid. The characteristic "rotten egg" odor and taste produced by this compound is not easily removed by aerating.

In order to remove coarser and finer suspended particles the water is subjected to *filtration*. For this the *sand filter* is generally used.

Larger sand filtration plants are constructed as follows: In large, water-tight containers a system of collecting conduits is arranged below. Above this a 12-inch layer of large boulders, then 4 inches of small boulders, or, instead, bricks loosely placed, then coarse gravel (3 inches), medium coarse gravel (5 inches), fine gravel (6 inches), coarse sand (2 inches), and finally fine sand (2 feet). Such a filter should be filled with water until the water stands one yard above the surface of the filter. The water is first allowed to stand quietly for about 24 hours, so that a film of settling substances will form on the sand filter. This represents the essential part of the filter, for which the sand and the remaining layers act only as carriers. While the sand permits nearly all bacteria to pass through, the filter film prevents this to a great extent. Through filtration the germ content of river water is reduced from several millions of bacteria to about 50-200. However, since the water is not entirely freed of bacteria through filtration, this filtration is not sufficient to render contaminated waters fit for use. The sand filter requires cleaning from time to time and the frequent removal of the slimy layer that is deposited on top.

For household use a miniature filtration plant can be constructed similarly to the one for the removal of iron, except that a layer of fine sand must be placed on top of the coarse sand.

Occasionally we find the sand filter replaced by the so-called stone filter. These filters in the form of hollow artificial stones made of washed river sand with sodium hydroxide lime silicate as binding agent, offer the advantage of economy of space and of longer uninterrupted serviceability, as the layer of dirt slips off of the outer perpendicular walls. The filtration takes place from the outside to the inside.

Contaminated water or water suspected of being contaminated may be freed of infectious agents through chemical *disinfection*, by boiling for 10 to 15 minutes, by filtering through a bacterial filter, or by ultraviolet light (provided most easily with a mercury quartz vapor lamp—precautions that are very rarely taken with water for animals). For veterinary hygienic purposes boiling and the chemical disinfection of water, which can be easily done and neither of which involves great expense, are the more practicable methods.

For chemical disinfection Schumburg suggests the following: Add to each liter of water 0.2 c.c. of a solution consisting of 20 gm. bromin, 20 gm. potassium bromin and 100 c.c. of water. After the resulting disinfection (5 minutes) the excess of bromin is bound with 0.2 c.c. of 9 per cent ammonia or with the Schumburg neutralizing salt consisting of 0.095 gm. sodium subsulphurosum, 0.04 gm. sodium carbonicum and 0.025 gm. mannite. According to Schueder and Engel, the Schumburg method is not entirely reliable.

For sanitary purposes a disinfection can also be effected by means of ozone or hydrogen peroxid. However, these procedures are as yet rather costly, so that they can not be considered for veterinary purposes.

To make *sea water* fit for consumption by animals on oversea transports it is distilled (apparatus of Pape and Henneberg, etc.). Air and carbonic acid are passed through the distilled water, and to every 50 liters of distilled water 2 gm. of sodium chlorid and 5 gm. of carbonate of lime are added.

E. Watering the Animals

In watering animals their *water requirements* should be considered. This is primarily dependent upon (1) the kind of animal (2) the water content of the feed, and (3) the amount of water given off through secretions (milk) and excretions. As has been fully explained on page 19, the temperature and humidity of the air as well as the physical exertion of the animal exercise a great influence upon the secretion (or excretion) of water through the skin and lungs.

For 1 kg. of air-dried feeds, sheep need about 2 liters of water, horses need about 2 to 3 liters of water, fat cattle about 3 to 4 liters of water, oxen, about 3 to 5 liters of water, cows, about 4 to 6 liters of water, hogs, about 6 to 8 liters of water.

This means that a large domestic animal requires 40 to 50 liters (10½ to 13 gallons), a small one 8 to 12 liters (2 to 3 gallons) of water daily.

The greater the water content of the feed, the less drinking water is needed. But we must take into consideration that the vegetable water contained in plants is absorbed with more difficulty than the water that is added to the feeding stuffs or simply consumed as drinking water, and because of this the former will not permanently and fully supply the total water requirement. Nevertheless the animals will naturally consume less drinking water if given feed containing much water (green feed, silage, turnips, etc., containing 75 to 90 per cent water) than if given dry feed (hay, straw, grain, oil cake, which contain only 10 to 15 per cent of water). Usually it is left to the animals to decide and to satisfy their own need of water.

Whether they drink a trifle too much or not quite enough is immaterial as a rule. Only with race horses is it customary to limit the amount of water as much as possible.

The assumption that an increased consumption of water results in an increased disintegration of protein has been refuted. An increased supply of water, if kept within physiological limits, results during the first days merely in an increased flushing of the body, washing out the accumulated nitrogenous decomposition products, but not in an increased disintegration of nitrogenous substances nor of other body or food elements. On the other hand, a continuous abnormally high consumption of water, as occurs less often from consumption of drinking water than from feed rich in water content, results in the dilution of the digestive juices, in overburdening the circulatory apparatus and in a lowering of the cell functions. Evident detriment can be recognized by a weak heart, anemia, digestive disturbances, etc. Insufficient water supply is of greater importance, for, as has been mentioned in the introductory part of this chapter, it results in severe disturbances and in extreme cases even in the death of the animals concerned.

When the amount of *water consumed* is not left to the choice of the animals by means of an automatic watering system, the horses are generally watered three times a day and as a rule before they receive their oats[1], and cattle twice a day, morning and evening, after the dry feeding, if water has not been added to their feed. Hogs very frequently have their entire water supply mixed with their feed, and sheep are usually given their water in low, wooden troughs, or, better still, in troughs of glazed stoneware, cement, sandstone, or in enamel or iron vessels, etc., to which they have constant access.

Care should be taken with overheated animals and after the consumption of feed liable to cause bloating (peas, beans, green feed, etc.). In the latter case animals are watered some time before and about two hours after feeding. In order to prevent overheated and thirsty horses from drinking too fast, bran is stirred into the water, or it is covered with hay and given intermittently with rests of about 5 to 10 minutes. It is advisable to wait after the first draught until the breathing has become somewhat quiet.

During hot weather after strenuous physical exertion (in the case of horses) and when animals are exhausted they should not only be watered at feeding times but at every opportunity, especially during hot summer evenings about two hours after feeding time.

The water is sometimes given in the manger, but usually in a pail. Wooden pails are used almost entirely because of their

[1]According to Tangl the efficiency of the feed is not lessened by watering either before, during, or after the feeding. On the other hand, the amount of water consumed is subject to important fluctuations, depending on the various methods of watering. The largest quantity of water was consumed by watering after feeding and the least by watering before feeding. All methods of watering agree equally well with animals if the method used is carried out regularly and consistently. Changes always produce slight disturbances.

durability and cheapness. From a sanitary point of view enameled

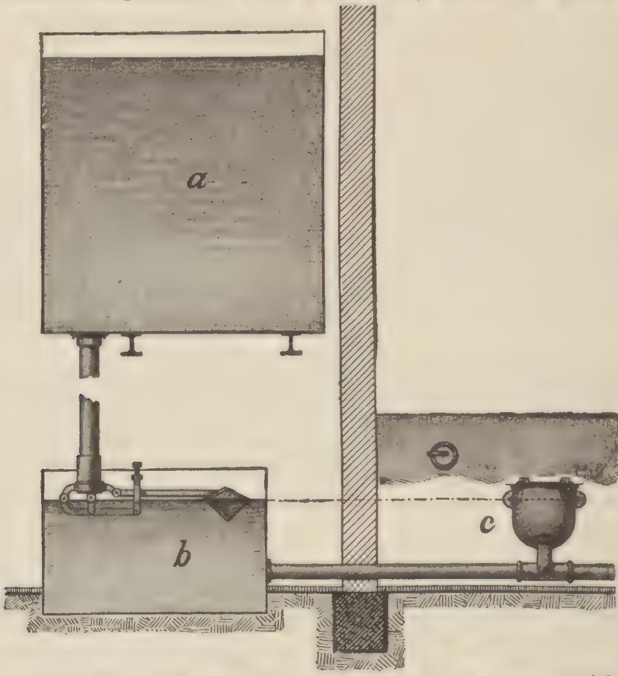


Fig. 43. Automatic drinking device. *a*, Reservoir; *b*, regulating basin; *c*, drinking basin.

metal pails are preferable, as they can be cleaned and disinfected so

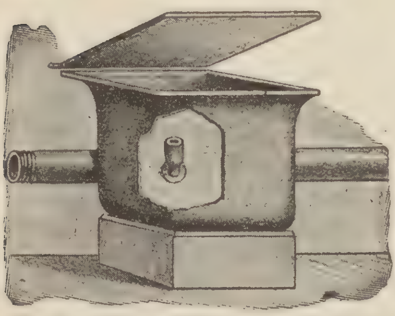


Fig. 44. Drinking basin or tub.

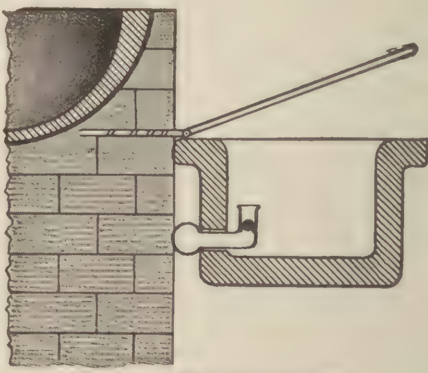


Fig. 45. Same as 44 but in cross section.

much more easily. Hygienically it is not recommended that animals should be watered at open troughs when the troughs are used by animals from different farms, as the spread of epizoötics is thus promoted.

Formerly greater stress was laid upon not giving drinking water

too cold[2], and to prevent this it was recommended that the water be allowed to stand for a while in containers or pails before using. If this is done in the (horse) stables the water absorbs ammonia from the air, is easily polluted with organic substances and becomes more or less a breeding place for bacteria. If the containers are placed in entrance ways, on cold days the water will be more apt to be chilled than to become warmer. The recent tendency is properly more and more to discard such practices. Water that is too warm has moreover been proved unsuitable for horses. According to Kettner, horses retain their winter hair longer if given warm drinking water to which crushed oats have been added; they sweat more easily and are less lively than with cold drinking water.

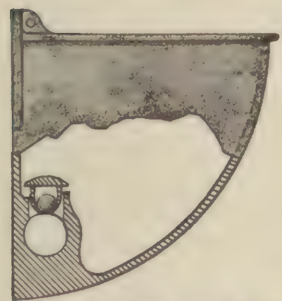


Fig. 46. Drinking trough with a ball valve on cross section.

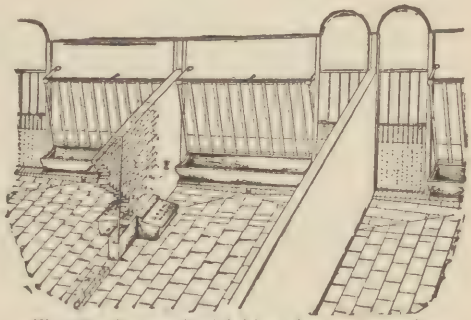
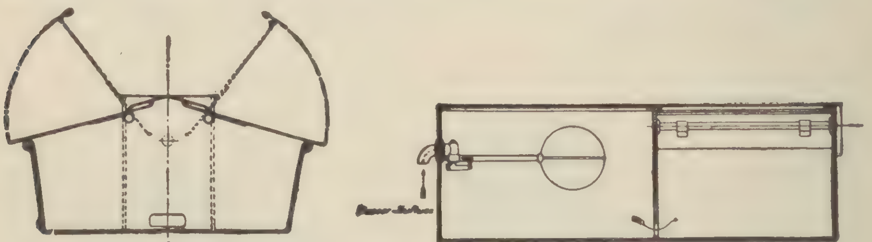


Fig. 47. Automatic drinking device for swine.

The animal should consume as much water as it requires and desires, and ordinarily should be able to quench its thirst at any time. To make this possible *automatic watering systems* have been devised. Such a system is shown in Figs. 43 to 49. It consists of a regulating basin which is directly connected by means of a water pipe with a drinking trough erected at the same height in the stalls. The flow of water in the regulating basin as well as in the drinking trough is automatically controlled by a float. It is best to provide the basins with separate floats or with closing ball valves in order to avoid a flowing back of polluted water. A lid is sometimes put on the trough, to prevent feed and dust from falling and decaying. The animals soon learn how to open the lid. To avoid the clattering of the lid Goezmann has constructed a simple, noiseless closing device.

[2]The loss of heat through drinking cold water may be considerable. If, for example, an ox or a cow consumes 50 liters (13 gallons) of water of 5° C. (41° F.) temperature daily, in order to bring this amount of water up to the body temperature of 39° C. (102° F.) about 1,700 calories will be required, for the production of which about ½ kg. (1.1 lb.) of digestible nitrogen-free extract must be metabolized. That amounts to about 15 per cent of the energy in the food which maintains a cow weighing 500 kg. (1,100 lbs.) live weight. With hogs, also, the consumption of cold water is apt to take no small part of the food for creating body heat. In the case of cattle which are being fed highly nutritious food and which give off a large surplus of thermal energy, the loss is in comparison considerably less, especially when the drinking water is consumed in numerous small rations, as is made possible by the automatic watering system, which in this case causes a direct saving of feed.

The automatic watering system was soon introduced into cattle barns, especially where milk cows were kept. It is a great boon there, as the frequent consumption of water increased the milk yield, according to Huntemann, 1½ liters per head daily. On the other hand, this watering system has not so far come into general use for work animals, especially horses, in fact, such use has even been advised against because it has been thought that the animals, when returning thirsty and overheated from their work to their stalls, would drink too greedily and too much and in that way invite harm. This supposition has been proved erroneous. In horse stables in which this system has been installed it has met with favor and the apprehensions have not been realized. Moreover, by shutting off the water troughs and installing zinc bars which prevent access to the water, it would be possible to prevent too early drinking, but this is not deemed necessary according to past experiences. Some horses occasionally splash the water out of the drinking trough. One of the automatic systems prevents this. The troughs in this system are practically empty, and the act of drinking causes the water to flow in automatically. Placing a small board on the water in other types of drinking receptacles prevents the water from being "slopped out." When drinking the horse pushes the board down. An arrangement to allow just enough room for drinking will have the same result.



Figs. 48 and 49. Automatic drinking devices for swine.

Recently automatic watering systems are also being recommended for sheep and hog stables (see Figs. 47-49).

Watering troughs should be emptied daily of bits of feed that have fallen in and should be cleaned weekly.

Section IV

Noxious Agents in Feeds

INTRODUCTION

This section will be devoted to the consideration of such noxious substances as are occasionally taken up by animals with their feed and exert an injurious effect upon their health. To avoid repetition, a number of substances that have been discussed elsewhere will not be discussed here. This applies to actinomycosis, anthrax and blackleg bacilli, etc. (cf. p. 67 and under "Pasture").

Our knowledge concerning noxious feed contaminations does not as yet rest upon very solid foundations. While many of these injurious substances have been definitely recognized, there exist, on the other hand, many plants and parasitic fungi to which injurious qualities have been attributed without any basis of fact. In regard to not a few of these supposedly injurious substances there exists a decided lack of agreement not only among recorded practical observations but also between the latter and the results of direct feeding experiments. In such cases it is frequently extraordinarily difficult to arrive at a correct conclusion as to the nature of the injurious principle in a suspected feeding stuff. In such cases one is by no means justified in condemning offhand, nor in accepting without question, either of two conflicting observations. It is well known, for instance, that the toxicity of certain plants varies according to the locality in which they grew, their stage of growth, etc.; e. g., lupines and digitalis. On the other hand, an animal's susceptibility to certain poisons varies according to species, breed, individual, fullness of stomach, general condition, age, and the extent to which it may have been accustomed to certain feed admixtures, foul pastures etc. For this reason negative results of feeding experiments should not be hastily accepted or generalized, especially when, as is frequently the case, such experiments for economic or other reasons have been conducted on minimum numbers of animals, even though maximum quantities of the suspected feeding material have been administered. Under natural conditions, on the other hand, these substances are usually taken up or eaten in minimum quantities, but by large numbers of animals, of which, as a rule, only a few, the susceptible individuals, become sick. Again, it is to be remembered that many plants, parasitic fungi, etc., which are perfectly harmless, are reputed to be poisonous Once a certain plant has been accused of possessing harmful properties, it is an easy matter for additional damaging, though only circumstantial, evidence to accumulate

against it, and thus, as time goes on, successful refutation becomes more and more difficult.

When noxious substances are present or suspected, and a search is made for them, certain poisonous or supposedly poisonous plants and fungi which may be present are usually easily recognized and too frequently divert the attention of the investigator from the real cause. The latter, more frequently than is usually suspected should be looked for among the bacteria. Supposedly poisonous plants, once they have attracted our attention, are too hastily accepted as explanations of existing troubles and reported or recorded as such. Thus our literature is burdened and the investigator confused with each additional so-called "proof" when it might have been an easy matter to settle the question at the time by a simple feeding experiment. In this connection a report by Werner is instructive.

Nine horses became affected with paralysis of the hind quarters. Scouring rushes were suspected as the cause. The hay in question contained 1.2 per cent oft his plant. The offending (?) rushes were removed and fed to an 8-year-old horse in good flesh, in maximum quantities of five pounds daily, or 60 pounds in the course of 20 days. No injurious effects whatever were observed At another time 51 horses became affected with paralysis of the hind quarters and disturbed heart action, and three died. The hay in question contained scouring rushes (*Equisetum palustre*). The latter were suspected as before. After their elimination the hay was fed to two horses, each receiving from 4 to 13 pounds daily, or 64 and 68 pounds respectively, in the course of ten days. No injurious effects followed. The hay in question, which, after removal of the rushes, had a musty odor and was therefore infected with mold fungi, was used in further experiments. More cases of sickness developed.

The scouring rushes were the most conspicuous foreign substances in the suspected hay, and they were erroneously accused as the cause of the poisoning. In reality they only masked the real cause.

The great variety of noxious feed admixtures are readily divided into three groups: (1) Poisonous plants; (2) diseases and contaminations of forage plants or feeding stuffs; (3) deterioration or spoiling of stored forage plants and feeding stuffs. This grouping will be used as a basis in the following discussions.

A. Poisonous Plants[1]

In the following pages poisonous plants will be discussed only in so far as they occur in pastures or gardens, that is, where animals have an opportunity to feed upon them in their green or dry state. The poisonous principles in the plants in question exert their effects either as local irritants of the mucous membrane of the alimentary tract (salivation, vomiting, diarrhea, colic, tympanitis, gastrointestinal inflammation), or their effects follow absorption into the tissues or into the general circulation and manifest themselves in changes of

[1] For information as to the principal poisonous plants affecting livestock in the range regions of the United States, the reader is referred to Bulletitn 575, U. S. Dept. of Agriculture, "Stock-Poisoning Plants of the Range," by C. Dwight Marsh, 1919, illustrated with colored plates, for sale by Superintendent of Documents, Government Printing Office, Washington, D. C., 50 cents.—J. R. M.

the blood (solution of the red corpuscles, hematogenic icterus, hemaglobinuria), or they have a stimulating or depressing effect upon the nervous system (fear, excitability, rage; stupefaction, drowsiness, fainting; trembling, spasms, convulsions, epileptiform attacks, etc., pareses or paralyses; abnormal or subnormal sensitiveness of the skin; dilation or contraction of the pupils, amaurosis, twitching of the eyes; intestinal paralyses and spasms; changes in the number and character of heart contractions, changes in the blood pressure, irregularity of blood and temperature distribution; respiration, pregnancy (abortion), etc., or the urinary apparatus, polyuria, albuminuria, retention of urine, etc. The plants enumerated below have not all been definitely proved to possess poisonous properties; some of them are merely suspected in this respect.

Poisoning by toxic plants is frequently difficult to recognize as such. In general the diagnosis is based upon the following points:

1. The anamnesis, which is usually very incomplete.

2. The sudden onset of the disease in previously healthy animals, its rapid course and fatal termination.

3. The appearance of the symptoms immediately, or soon, after feeding.

4. The simultaneous affection of a number of animals.

5. Symptoms of disturbance of the nervous system, the digestive organs (stomach) and of the kidneys. Some intoxications are attended with and recognized by characteristic antemortem and postmortem symptoms.

6. Chemical analysis or demonstration of the presence of the poison.

From a differential diagnostic point of view the following are of importance: Anthrax, perforation of stomach or intestine, incarcerated hernia, volvulus and intussusception of the intestines, infectious abortion, as well as abortion from other causes.

The treatment of intoxications consists in the prompt removal of the toxins by inducing vomiting, or per annum or by diuretics, emollients for local irritations (linseed decoctions, etc.), preventing absorption by the administration of astringents and precipitants (tannin, sulphate of copper, etc.), reducing the toxic action (potassium iodide solution ?) or the use of antidotes, atropin for nicotin, veratrin, morphin and muscarin poisoning; morphin for atropin and related alkaloids; strychnin for conein; coffein for morphin, etc.; in general, symptomatic treatment.

Preventive measures consist in the destruction of toxic plants wherever found in pastures, meadows and feed-lots. On pastures animals usually avoid poisonous plants instinctively. Instinct alone, however, is not an absolute safeguard against poisoning on pastures, statements frequently made to this effect notwithstanding. In stable-

fed animals instinct is of even less protective value, especially when feed is offered in a finely divided state, as chaffed feed, meal, etc. Especial care should be observed in the feeding of garden products or waste (weeds, clippings from ornamental plants), since many of these plants are poisonous. When the harmlessness of certain plants or offal is not certainly known, it is best to refrain from feeding them at all, their value at best being insignificant when compared with the possible danger following their feeding[1].

Persistent warfare against poisonous plants in field and meadow as well as against weeds in general is advisable not only from a hygienic point of view but also for politico-economic and general sanitary reasons. Braungart estimates the annual loss from weedy fields in many sections of Germany at about 25 per cent (1899). There are many vegetable poisons which in their original form are harmless to the animal body, yet are excreted in more virulent form with the milk and may thus endanger the health and life of human beings, especially infants. Coarse and woody plants, in themselves of inferior value and frequently injurious, retard the curing or drying process in damp weather and induce molding.

The astonishing rapidity with which weeds can multiply is explained by the fact that one individual plant of a species of field crowfoot produces 2,000 seeds, field mustard 2,000, corn cockle 3,000, horse thistle, 4,500, coltsfoot 5,000, ox-eye daisy 12,000, sow thistle (*Sonchus*) 19,000, poppy 50,000, chamomile 50,000. Warfare on weeds should be encouraged by educational means, by state and government appropriations of funds, the offering of premiums for weed-free farms and fields, periodical inspections of the latter, etc.

In the consideration of plans for the extermination of weeds, special consideration should be given to vacant lots in cities and suburbs, lanes and roads, the borders of ditches, river channels and public dumping grounds, as breeding places of noxious and useless weeds. As a rule such places are neglected in this connection. Such places should be mowed at least twice each year. This would prevent the weeds from going to seed and would be of benefit to the useful grasses.

Sweepings from barns, feed bins and granaries, which are nearly always infested with weed seeds, are usually thrown on the compost or manure heap without further ceremony and thence carried to the fields and meadows. Such infested material should be destroyed by burning or made harmless by treatment with unslaked lime or acids.

For the sake of brevity, a list of important poisonous plants with their principal characteristics, is given below. For assistance in the

[1]Marsh (U. S. Dept. Agr., Farmers' Bul. 720) points out that most losses of livestock from poisonous plants on the western ranges are more or less closely connected with a lack of suitable forage, and that as a rule animals eat poisonous plants only under stress of necessity. A sufficiency of good forage, therefore, will usually prevent such losses. He recommends the destruction of the poisonous plants in some cases, the use of the range when the plants are not poisonous in other cases, and careful management in driving and handling stock.—J. R. M.

identification of individual species, text-books on botany should be consulted. For convenience in reference the Latin names are given and arranged in alphabetical order. (See p. 118.)

I. Cryptogams

1. Scouring rush. **Equisetum.** No. 40.
2. Fungi or toadstools. **Amanita, Russula, Boletus,** etc. No. 9.
3. Brake fern. **Pteridium aquilinum.** No. 75.

II. Phanerogams

A. Gymnosperms.

1. Yew. **Taxus.** No. 90.
2. Juniper. **Juniperus sabina.** No. 50.
3. Cedar. **Juniperus virginiana.** No. 51.
4. Pine, fir, spruce. No. 69.

B. Angiosperms.

A. Monocotyledons:

1. Daffodils. **Narcissus.** No. 59.
2. White hellebore. **Veratrum album.** No. 91.
3. Meadow saffron. **Colchicum autumnale.** No. 30.
4. Onion. **Allium cepa.** No. 8.
5. Narthecium. No. 60.
6. Truelove. **Paris quadrifolius.** No. 66.
7. Arum. **Arum maculatum.** No. 14.
8. Lily of the valley. **Convallaria majalis.** No. 32.
9. Solomon's seal. **Polygonatum multiflorum.** No. 70.
10. Bearded darnel, poisonous darnell or furrow weed, **Lolium temulentum.** No. 55.
11. Fin's grass, (mat grass), **Nardus stricta.** No. 59-b.

B. Dicotyledons:

a. Papilionaceæ:

1. Laburnum. **Cytisus laburnum.** No. 35.
2. Everlasting pea, chick-pea. **Lathyrus,** several species. No. 52.
2. Goat's rue. **Galega officinalis.** No. 44.
4. Locust. **Robinia pseudacacia.** No. 81.
5. Moon bean. **Phaseolus lunatus.** No. 67.
6. Japanese sophora. **Sophora japonica.** No. 88.

b. Umbelliferæ:

1. Water hemlock. **Cicuta virosa.** No. 27.
2. Spotted hemlock. **Conium maculatum.** No. 31.
3. Fool's parsley. **Æthusa cynapium.** No. 5.
4. Chervil. **Myrrhis temula, s. Chærophyllum temulum.** No. 58.

5. Cow parsnip. **Heracleum spondilium.** No. 48.
6. Water parsnip. **Sium latifolium.** No. 86.
7. Water-drop wort, dead tongue, hemlock. **Œnanthe crocata** and **Œ. fistulosa.**

c. Amygdalaceæ:
1. Peach. **Amygdalus, s. Prunus persica.** No. 10.
2. Cherry laurel. **Prunus laurocerasus.** No. 74.
3. Plum. **Prunus domestica.** No. 73.
4. Cherry. **Prunus cerasus** and **P. avium.** No. 73.

d. Silenaceæ:
1. Corn cockle. **Agrostemma githago.** No. 6.

e. Cruciferæ:
Horseradish. **Cochlearia armoracia.** No. 29.
2. Mustard. **Sinapis.** No. 85.
Hedge mustard. **Erysimum cheiranthoides** and **E. crepidifolium.** No. 41.
4. Wild radish. **Raphanus raphanistrum.** No. 78.
5. Garden radish. **Raphanus sativus.** No. 79.
6. Rape and rutabaga. **Brassica napus.** No. 17.
Bitter cress. **Cardamine pratensis.** Cuckoo flower. No. 22.

f. Hypericaceæ:
1. St. John's wort. **Hypericum.** No. 49-b.

g. Papaveraceæ:
1. Poppy. **Papaver rhœas** and **P. argemone.** No. 65.
2. Celandine, swallow-wort. **Chelidonium majus.** No. 25.

h. Celastraceæ:
1. Spindle tree, prickwood. **Euonymus europea.** No. 43.

i. Ranunculaceæ:
1. Pheasant's eye. **Adonis.** No. 4.
2. Cursed crowfoot. **Ranunculus sceleratus,** also **R. acer** and **R. arvensis.** No. 77.
3. Pasqueflower. **Pulsatilla pulsatilla** and **P. pratensis.** No. 77.
4. Wind flower. **Anemone nemorosa.** No. 11.
5. Christmas flower, Christmas rose, black and green, hellebore. **Helleborus.** No. 47.
6. Wolf's bane, monk's hood, aconite. **Aconitum.** No. 3.
7. Larkspur. **Delphinium.** No. 38.
8. Clematis, lady's bower. **Clematis.** No. 28.
9. Marsh marigold. **Caltha palustris.** No. 26.

j. Salicaceæ:
1. Cottonwood. **Populus balsamifera.** No. 72.

k. Asclepidaceæ:
  1. Swallow-wort, celandine. **Cynanchum, s. Vincitoxicum.** No. 34.

l. Solanaceæ:
  1. Nightshade. **Solanum nigrum.** No. 87.
  2. Bittersweet. **Solanum dulcamara.** No. 87.
  3. Belladonna, deadly nightshade, banewort, dwale. **Atropa belladonna.** No. 15.
  4. Jimson, Jamestown weed. **Datura stramonium.** No. 37.
  5. Henbane, stinking nightshade. **Hyoscyamus niger.** No. 49.
  6. Tobacco. **Nicotiana.** No. 62.

m. Convolvulaceæ:
  1. Dodder. **Cuscuta epithymum.** No. 33.

n. Scrophulariaceæ:
  1. Foxglove. **Digitalis purpurea,** etc. No. 39.
  2. Hedge hyssop. **Gratiola.** No. 46.
  3. Cow wheat. **Melampyrum.** No. 56.
  4. Yellow rattle. **Alectorolophus.** No. 7.

o. Labiatæ:
  1. Ground ivy, ale hoof, gill. **Glechoma hederacea.** No. 45.

p. Rhodoraceæ:
  1. Rhododendron. No. 80.

q. Thymelaceæ:
  1. Laurel herb. **Daphne.** No. 36.

r. Euphorbiaceæ:
  1. Spurge. **Euphorbia.** No. 42.
  2. Mercury. **Mercurialis.** No. 57.

s. Buxaceæ:
  1. Boxwood. **Buxus sempervirens.** No. 19.

t. Polygonaceæ:
  1. Sour dock. **Rumex.** No. 82.
  2. Peach-leaved knotweed. **Polygonum persicaria.** No. 71.

u. Cannabinaceæ:
  1. Hemp. **Cannabis sativa.** No. 21.

v. Compositæ:
  1. Cornflower or bluebottle. **Centaurea cyanus.** No. 23.
  2. Tansy. **Tanacetum vulgare,** etc. No. 89.

w. Aristolochiaceæ:
  1. Birthwort. **Aristolochia clematis.** No. 13.

x. Oxalidaceæ:
   1. Wood sorrel. **Oxalis acetocella.** No. 64.

y. Linaceæ:
   1. Flax. **Linum catharticum.** Purging or mountain flax (European).

z. Apocynaceæ:
   1. Oleander. **Nerium oleander.** No. 61.

The Most Important Poisonous Plants

1. **Abies s. Pinus. See No. 69.**
2. **Aconitum lycoctonum.** Aconite, wolf's bane, monk's hood. Ranunculaceæ.
   Poison: Alkaloids—lycaconitin, myoctonin.
   Toxic parts: Same as No. 3.
   Toxic action: Same as No. 3.
3. **Aconitum napellus, A. neomontanum, A. variegatum.** True, etc., monk's hood. Ranunculaceæ.
   Poison: Alkaloid—aconitum.
   Toxic parts: Tubers, flowers, leaves, stems (less before blooming); also toxic in dried state.
   Toxic action: Gastroenteritis paralysis, unconsciousness, cerebritis (sheep).
   Animals susceptible: Horses, cattle, sheep, goats, swine.
   Treatment: Subcutaneous injections of eserin and atropin.
4. **Adonis vernalis** and **A. æstivalis.** Pheasant's eye. Ranunculaceæ.
   Poison: Glucosid—adonidin.
   Toxic parts: Leaves and tops.
   Toxic action: Similar to that of the digitalis alkaloids (No. 39).
5. **Æsthusia cynapium.** Fool's parsley. Umbelliferæ.
   Poison: ?
   Toxic parts: Leaves or tops?
   Toxic action: Reputedly similar to that of spotted hemlock, possibly confused with the latter.
   Animals susceptible: Horses, cattle, sheep (unaffected by 2 to 4 pounds of the green tops).
6. **Agrostemma githago.** Corn cockle. Silenaceæ.
   Poison: Agrostemma sapotoxin or githagin. Amount variable, average 6.6 per cent. Lethal dose, according to Brandl 10 to 12 gm. per kg. live weight. Poison destroyed by roasting.
   Toxic parts: Seed.
   Toxic action: Irritation of mucous membranes of eyes, nose, mouth and gastrointestinal tract (inflammation and gangrene), hemolysis, hemorrhages, hemoglobinuria, excitation of nerves followed by paralysis (disturbance of equilibrium, apathy, convulsions), cardiac paralysis, death.
   Susceptibility of animals variable: Horses (clinical symptoms of spinal meningitis), swine, cattle, sheep, pigeons, dogs. Poultry immune according to Albrecht; 15 gm. per kg. live weight fatal according to Brandl and Mueller. Miessner fed a mixture of vetches containing 20 per cent of corn cockle to three chickens for a week, without harmful results. According to Degen, death followed in chickens when 20 per cent of the daily ration consisted of a meal containing 40 to 50 per cent of corn cockle. According to Duill, daily administration of 77 gm. (total 1,540 gm.) to a horse for a period of three weeks caused poisoning. According to Ludewig, 300 gm. of corn cockle seed per day causes violent poisoning in horses. Pusch fed horses not exceeding 2 lbs. of corn cockle seed per day for periods of 5 to 9 days. Only a few of them became affected with slight inflammation of the buccal mucous membrane, throat, stomach, and upper air passages, the others remained well. Hagemann fed mixtures containing 6 per cent of cockle seed to growing, pregnant, suckling and fattening hogs, also cattle weighing

1,200 pounds, 5 lbs. of cockle seed, without observing ill effects. Butter from cows thus fed was crumbly and rancid. The pigs from sows thus fed did not thrive. Hansen observed no ill effects from such feeding, but the butter was of inferior quality. Miessner fed pigs weighing 36 lbs. with 1 lb. of a mixture of vetch seed containing 20 per cent cockle seed for ten days. The animals thrived.

When fed in very large quantities to horses and oxen (10 lbs. daily with 80 per cent cockle seed) fatal results follow (Perussel). According to Ludewig, daily administrations of 300 gm. produce violent illness, while Brandl found daily doses of 700 gm. without effect. Sturm found that 4 to 6 lbs. daily for years produced no ill effects, while one calf died from the effects of a single dose of 400 gm. Sheep would consume 1,200 gm. in the course of 60 days and 1,100 gm. in the course of 30 days with practically no reaction.

A goat receiving 300 to 500 gm. daily for a period of 21 days died, while 100 to 150 gm. daily, administered for weeks had no ill effects.

Swine, according to certain authors, can consume 5,420 gm. in 20 days, or 500 gm. daily for months, or 6,350 gm. in 82 days, without ill effects, while on the other hand daily doses of 50 to 100 gm. (in one instance 20 to 100 gm. daily) for two weeks produced fatal results. According to Pusch, cattle and sheep can consume larger quantities of cockle seed without ill effects than it is possible for them to obtain under natural conditions. This observation of course applies only to animals in good health. Healthy digestive juices split up the sapotoxin into harmless compounds. In the presence of gastric catarrh, etc., this splitting process may not take place and cockle-seed poisoning results.

7. **Alectorolophus minor** and **A. major.** Yellow rattle. Scrophulariaceæ, same as **Melampyrum,** No. 56.

8. **Allium cepa.** Onion. Liliaceæ.
Action: Gastroenteritis, constipation, moderate diarrhea, vomiting.
Animals susceptible: Cattle.

9. **Amanita bulbosa, muscaria, Boletus luridus, B. satanas, Hypholoma fasciculare, Lactarius torminosus, Russula emetica, Scleroderma vulgare, (potato puffball), Amanita umbrina, etc.** Fungi: Toadstools, mushrooms, puffballs, etc.

Poison: Toxic albumins—amanitatoxin, alkaloids (muscarin), muscaridin (fungus-atropin), cholin, phallin, agarazinic acid, luridic acid, helvellic acid, active irritating substances (resins and resin acids). Boiling and drying to a great extent destroy the poisonous properties.

Toxic action: Gastroenteritis (vomiting, colic, diarrhea), cerebral symptoms (pschysic, motor and secretory excitability followed by corresponding depression), collapse, and icterus. Postmortem findings: Inflammation of the digestive tract, hemorrhages in subpleural, pulmonary and subcutaneous connective tissues, fatty degeneration of the kidneys, liver, heart.

Susceptibility: **Amanita bulbosa,** geese. **A. muscaria,** horses, sheep (according to some reports not susceptible), geese. **Helvella esculenta,** dogs. **Hypholoma fasiculare,** guinea-pigs.

Insusceptible: **Amanita bulbosa,** swine, rabbits, guinea-pigs. **A muscaria,** sheep, (according to some reports susceptible), goats, swine, rabbits, guinea-pigs, fish and crayfish. **Boletus luridus,** dogs. **Boletus satanas,** cattle, sheep, swine, dogs. **Hypholoma fasiculare,** rabbits, poultry, pigeons. **Lactarius torminosus,** swine (fungi fed dried or boiled), rabbits, guinea-pigs. **Russula emetica,** swine (fungi fed dried or boiled), rabbits, guinea-pigs. Mixtures of **Lactarius torminosus, Scleroderma vulgare, Aminita umbrina,** "Gallenbitterling," "Gruenling" and "Tintenpilz," goats (fungi boiled), rabbits.

As to the toxic action of **Boletus lupinus, Scleroderma vulgare** and **Amanita umbrina,** which are toxic for man, no observations on domestic animals are recorded. The same is true of **Boletus piperatus,** suspected of toxicity for man, also **Cantharellus aurantiacus, Lactarius necator, Russula fragilis, Boletus felleus** (inedible on account of nauseating taste and

smell), **Boletus pachypus, Lactaria rufa, Inoloma traganus, Russula fetidus, Ithyphallus impudicus** and **Elaphomyces granulatus.**

10. **Amygdalus s. Prunus persica.** Peach. Amygdalaceæ.
Poison: Glucosid—amygdalin, prussic acid from the latter.
Toxic parts: Leaves and pits.
Toxic action: Staggering, spasms of extensors, mydriasis, spasms of respiratory muscles, general paralysis.
Animals susceptible: Cattle, goats.

11. **Anemone nemorosa.** Wind flower. Ranunculaceæ.
Poison: Formerly erroneously considered non-poisonous.
Toxic parts: Root and tops; no effect when fed in dry state. Fruit-bearing plant more active in effects than flowering stage.
Toxic action: No loss of appetite, no diarrhea, diuretic but not irritant. Discoloration of urine in dogs due to pigment contained in plant; does not occur in horses, cattle or goats. Milk has odor and taste of anemone; slight bloodiness of milk (congestion).
Animals susceptible: Horses, cattle, goats, dogs.

12. **Anemone pulsatilla** and **H. pratensis.** See **Ranunculus,** No. 77.

13. **Aristolochia clematis.** Birthwort. Aristolochiaceæ.
Poison: Alkaloid—aristolochin.
Toxic parts: Tops.
Toxic action: Excitement, depression, weakness of hind extremities, drowsiness, midriasis, accelerated heart action, constipation, gastritis.
Animals susceptible: Horses, cattle.

14. **Arum maculatum.** Arum. Araceæ.
Poison: Irritant, volatile, etherial oil (arumtoxin).
Toxic parts: Tops.
Toxic action: Dermatitis, dyspnea, trembling, paralysis.
Animals susceptible: Horses.

15. **Atropa belladonna.** Belladonna, deadly nightshade, baneworth, dwale. Solanaceæ.
Poison: Alkaloids—atropin, hyoscyamin.
Toxic parts: Young roots, fully developed roots and entire plant.
Toxic action: Mydriasis, cerebral excitement, accelerated heart action, followed by paralysis of the voluntary muscles, cerebritis (sheep).
Animals susceptible: Horses and cattle (120 to 180 gm. of the tops or 60 to 90 gm. of the roots, violent poisoning; 180 gm. fatal), Goats (1½ lbs. dried leaves, midriasis and blindness), sheep.

16. **Boletus luridus** and **B. satanas.** See **Amanita,** No. 9.

17. **Brassica napus.** Rape, rutabaga. Cruciferæ.
Poison: Sinigrin and sinalbin; derivative, allyl, mustard oil.
Toxic parts: Tops in blossom.
Toxic parts: Gastroenteritis, irritation of kidneys.
Animals susceptible: Cattle when fed exclusively on rape.

18. **Brassica nigra.** Black mustard. See **Sinapis,** No. 85.

19. **Buxus sempervirens.** Box tree. Buxaceæ.
Poison: Alkaloid—buxin.
Toxic parts: Leaves.
Toxic action: Dizziness, stupor, convulsions, gastroenteritis (the latter may be absent).
Animals susceptible: Horses (1½ lbs. kill in short time), cattle, swine.

20. **Caltha palustris.** Marsh marigold. Ranunculaceæ.
Poison: Anemonol (anemone camphor, anemonin), cholin (about 1 per mil).
Toxic parts: The more mature parts of the plant.
Toxic action: Gastroenteritis, irritation of the kidneys, decreased milk secretion.
Animals susceptible: Horses, cattle.

21. **Cannabis sativa.** Hemp. Cannabinaceæ.
Poison: Narcotic poison in the pistillate plant (hashish).
Toxic parts: Tops.

Toxic action: Colic, vertigo, muscular trembling, throbbing heart action.
Animals susceptible: Horses.

22. **Cardamine pratensis.** Bitter cress, cuckoo flower. Cruciferæ.
Toxic parts: Green tops in full bloom, not in dry state.
Toxic action: Deer.
Animals susceptible: Horses.

23. **Centaurea cyanus.** Cornflower, bluebottle. Compositæ.
Poison: ?
Toxic parts: Tops.
Toxic action: Paraplegia, terminating in recovery.
Animals susceptible: Cattle.

24. **Chærophyllum temulum.** Chervil. See **Myrrhis temula,** No. 58.

25. **Chelidonium majus.** Celandine, swallow-wort. Papaveraceæ.
Poison: Alkaloids—chelidonin and chelerythrin.
Toxic parts: Roots.
Toxic action: Inflammation of the alimentary canal, paralysis of central nervous system.
Animals susceptible: Horses and cattle (quantities less than one pound, harmless), sheep (three to five handfuls harmless).

26. **Cicer arietinum.** Everlasting pea, chick-pea. See **Lathyrus cicer, No. 52.**

27. **Cicuta virosa.** Water hemlock. Umbelliferæ. (Rootstock hollow, transversely septated, leaves 2 to 3 pinnate with linear lanceolate sharply serrated leaflets. Peculiar, aromatic, celery-like odor).
Poison: Cicutoxin (not destroyed by drying).
Toxic parts: All parts of the plant.
Toxic action: Local—irritant (gastroenteritis), tympanitis. Systemic—muscular spasms, accelerated pulse, oppressiveness, weakness, paralysis, death.
Animals susceptible: Horses, cattle, swine, goats and sheep.

28. **Clematis vitalba, C. recta, C. flammula.** Lady's bower, etc. Ranunculaceæ.
Poison: Clematin.
Toxic parts: Entire plant. (Poison destroyed by cooking or drying.)
Toxic action: Gastroenteritis.

29. **Cochlearia armoracea.** Horseradish. Cruciferæ.
Poison: Pungent substances (ethereal oils).
Toxic parts: Roots.
Toxic action: Inflammation of the organs of digestion.
Animals susceptible: Cattle.

30. **Colchicum autumnale.** Meadow saffron. Colchicaceæ.
To exterminate, cultivation and draining of the soil is recommended, or destruction of the bulbs with a sharp spud 2 inches wide.
Poison: Alkaloid—colchicin (cumulative action, not destroyed by heat, excreted with the milk) and colchicein.
Toxic parts: Leaves, blossoms, fruit capsules (also in dried state), especially when mixed with chaffed feed, forcing animals to eat it.
Toxic action: Usually manifested after 12 to 24 hours, salivation, vomiting, colic, diarrhea, gastroenteritis, weak pulse, mydriasis, stupor, unconsciousness, weakness, gangrenous dermatitis, irritation of kidneys (hematuria), death from paralysis of respiratory centers. Postmortem: Imperfectly coagulated, dark blood.
Animals susceptible: Horses, cattle, sheep, swine (3 to 5 lbs. of green fruit capsules and green leaves or 4 to 5 lbs. of the dried plants, fatal to cattle, poison excreted in milk).

31. **Conium maculatum.** Poison hemlock, wild hemlock, spotted lemlock, spotted parsley. Umbelliferæ. (As a rule growing on waste or uncultivated land, dumping places, compost heaps, along fences. When rubbed leaves have odor of cat's urine. Stem naked, finely ribbed, spotted with red; petiole round, hollow.)
Poison: Alkaloid—Conin (not destroyed by drying); conhydrin and methylconiin.
Toxic parts: Entire plant, especially seeds and leaves, when in blossom.
Toxic action: Irritant (salivation, tendency to vomit, gastroenteritis. Stupor, convulsions, paralysis, death.

Animals susceptible: Horses (3.5 lbs. in fresh state, no effect), cattle (3 lbs. fresh, no effect; one-half pound dried tops, effective), calves, sheep, goats, swine.

32. **Convallaria majalis.** Lily of the valley. Liliaceæ.
Poison: Convallamarin and Convallarin.
Toxic parts: Parts above the ground.
Toxic action: Symptoms of digitalis poisoning (see **Digitalis,** No. 39).
Animals susceptible: Geese.

33. **Cuscuta epithymum.** Dodder. Convolvulaceæ.
Toxic parts: Fresh tops. Harmless when dried and chopped.
Toxic action: Cramps, especially of hind legs; not fatal.
Animals susceptible: Young cattle, horses (diarrhea).

34. **Cynanchum** s. **Vincitoxicum vincitoxicum.** Celandine, swallow-wort. Asclepiadaceæ.
Poison: Glucosid—asclepiadin.
Toxic parts: Tops.
Toxic action: Vomiting, diarrhea, inflammation of bladder and kidneys, paralysis, convulsions with asphyxia.
Animals susceptible: Sheep.

35. **Cytisus laburnum.** Laburnum. Papillionaceæ.
Poison: Alkaloid—cytasin.
Toxic parts: Bark, leaves, blossom buds, green pods, seeds, sprouts of seeds.
Toxic action: Local—irritant (salivation, vomiting, colic, diarrhea). Systemic—excitation of nervous system, followed by paralytic symptoms (dysphagia and paralysis), muscular weakness in hind extremities, paralysis of fore-body and of fore legs, cardiac weakness, dyspnea, dullness.
Animals susceptible: Horses (excessively), cattle, swine, sheep and goats slightly; rabbits and poultry apparently insusceptible. Mature animals more susceptible than young ones.

36. **Daphne mezereum** and **D. laureola.** Laurel herb. Thymelaeaceæ.
Poison: Resin—mezerein (blistering properties).
Toxic parts: Bark, leaves less so.
Toxic action: Nausea. colic, diarrhea, dizziness, exhaustion, cough, irritation of urinary apparatus, diaphoresis, gastritis.
Animals susceptible: Horses (30 gm. of the dried leaves, fatal).

37. **Datura strammonium.** Jimson weed, Jamestown weed. Solonaceaæ.
Poison: Poisonous parts and toxic action same as for **Atropa belladonna,** No. 15.
Animals susceptible: Cattle, horses.

38. **Delphinium consolida, D. elatum, D. ajacis.** Larkspur. Ranunculaceæ.
Poison: Alkaloid—delphinin, resembles veratrin.
Toxic action: Colic, anesthesia, death.
Animals susceptible: Horses, cattle, rabbits (sheep are not susceptible).

39. **Digitalis purpurea, D. lutea, D. ambigua.** Red, yellow and pale yellow fox glove. Scrophulariaceæ.
Poison: Glucosids—digitonin, digitalin, digitalein, digitoxin.
Toxic parts: Leaves especially.
Toxic action: At first excitation of vagus (retarded heart action) and of the vasomotor nerves (increased blood pressure), followed by paralyzing effect; irritation of mucous membrane of digestive tract. 100 to 200 gm. of fresh leaves fatal to horses, 25 gm. of dried leaves same effect. On the other hand, 120 gm. of dried leaves fed four days in succession to cattle or 80 gm. of dried leaves fed to goats eight days in succession, or 47 gm. fed to sheep for seven days, had no effect.
Animals susceptible: Horses, cattle, sheep, swine.

40. **Equisetum arvense.** Horsetail, scouring rush. **E. pallustre, E. Silvaticum, E. hiemale, E. limosum, E. quisetinæ.** No reports relative to **E. Maximum and E. pratense** available. The same applies to rare species **E. variegatum** and **E. ramosissimum,** which according to Lohman, are non-toxic.

Poison: Alkaloid—equisitin. No aconitic acid, as assumed by Ludewig.
Toxic parts: Tops.
Toxic action: Mental excitement and increased reflex excitability, followed by paralysis of cerebellum and spinal cord (staggering gait, paraplegia, paralysis of bladder, tail and penis), unconsciousness, coma. In chronic poisoning, interruption of nutrition, reduced milk secretion, cachexia. Postmortem: Hyperemia and pronounced serous infiltration of the cerebellar and spinal meninges.
Animals susceptible: **E. arvense**—horses (Thomas), but according to other reports horses are not susceptible. **E. palustre**—horses, cattle and rabbits, though according to some reports horses and cattle are not susceptible). **E. limosum** and **E. hiemale**—horses. Geese according to Ludewig are not susceptible to **E. hiemale.** He recommends extermination of scouring rushes by pasturing with geese. According to Dammann, sheep can take 3 to 4 lbs. of **E. palustre** daily without harm. According to **Pancerzynski, E. limosum** is toxic for horses, which agrees with the teachings of Viborg, Nielsen, Hertwig, Haubner and others. Hay containing one-half its weight of **E. palustre** fed to horses or cattle, or containing one-third its weight of **E. palustre** and fed to sheep and rabbits, produced fatal results in horses in the course of 4 to 6 weeks, and in the cattle and sheep it produced emanciation and diarrhea (Pancerzynski). (Cf. p. 100.)

41. **Erysimum cheiranthoides** and **E. crepidifolium.** Hedge mustard. Cruciferæ.
Poison: Probably same as in **Sinapis,** No. 85.
Toxic parts: Tops and seeds.
Toxic action: Same as in **Sinapis,** No. 85.
Animals susceptible: Cattle, geese (Zopf, Grimme).

42. **Euphorbia cyparissias, E. peplus, E. helioscopia.** Spurge. Euphorbiaceæ.
Poison: Pungent (?) substance.
Toxic parts: Tops.
Toxic action: Produces local inflammation in mouth, stomach, intestine.
Animals susceptible: Cattle and sheep. Goats are said to resist the toxic effect of these as well as of most other species of Euphorbiaceæ, although, according to Prietsch, **E. peplus** is toxic for goats also. According to Dammann a sheep was fed 3 lbs. of **E. helioscopia** without injurious effects.

43. **Euonymus europea.** Spindle tree or prickwood. Celastraceæ.
Poison: Resin—evonymin.
Toxic parts: Leaves.
Toxic action: Diarrhea, vomiting, death.
Animals susceptible: Sheep, goat.

44. **Galega officinalis.** Goat's rue. Papillionaceæ.
Poison: Unknown.
Toxic parts: Stems and leaves.
Toxic action: Dyspnea, tympanitis, slight inflammation of abomasum, congestion of the kidneys. Death by asphyxia.
Animals susceptible: Sheep (3 kg. fatal). Rabbits and guinea-pigs not susceptible.

45. **Glechoma hederacea.** Ground ivy, alehoof, gill over the ground. Labiatæ.
Poison: Ethereal oil (?)
Toxic parts: Tops(?)
Toxic action: Dyspnea, cyanosis, accelerated pulse, palpitation of the heart.
Animals susceptible: Horses; not cattle nor sheep.

46. **Gratiola officinalis.** Hedge hissop. Scrophulariaceæ.
Poison: Glucosid—gratiolin and gratiolicin (said to be excreted with the milk).
Toxic parts: Tops.
Toxic action: Hemorrhagic gastroenteritis; in swine, vomiting also.
Animals susceptible: Horses, cattle, swine, sheep.

47. **Helleborus niger, H. fetidus, H. viridus.** Black, stinking and green hellebore. Ranunculaceæ.

Poison: Glucosids—helleborein and helleborin. Traces in **H. niger and H. fetidus**, more in **H. viridus.**

Toxic parts: Roots and radial leaves (fresh as well as dried).

Toxic action: Local—irritant (salivation, vomiting, bloody diarrhea). Systemic—at first retarded, later accelerated heart action, increased blood pressure followed by pronounced decrease (heleborein), excitement, stupor, death with spasms (helleborin).

Animals susceptible: Horses, cattle, sheep, mules.

48. **Heracleum sphondylium.** Cow parsnip. Umbelliferæ.

Poison: According to Ludewig, nontoxic. According to Honecker, toxic when fresh.

Toxic parts: Tops.

Toxic action: Salivation, groaning, weak pulse, termination in recovery.

Animals susceptible: Cattle.

49. **Hyoscyamus niger.** Henbane or stinking nightshade. Solanaceæ.

Poison: Alkaloids—hyoscin and hyoscyamin.

Toxic parts: Roots and tops.

Toxic action: Dilation of pupils, cerebral and cardiac excitation, followed by paralysis of voluntary muscles.

Animals susceptible: Horses, cattle, poultry.

49b. **Hypericum perforatum, H. crispum, H. maculatum.** St. John's wort. Hypericaceæ.

Poison: Fluorescent pigments—hyperizin (yellow, soluble in alcohol) and hypericum (red, soluble in petrol-ether).

Toxic parts: Tops.

Toxic action: Photodynamic (see p. 37) (light disease, optic sensitization disease), dermatitis, dullness.

Animals susceptible: Animals with unpigmented skin, white marks. Horses, sheep.

49c. **Hypholoma fasciculare.** See No. 9.

49d. **Inoloma and Ithyphallus.** See No. 9.

50. **Juniperus sabina s. Sabina sabina.** Juniper. Coniferæ.

Poison: Ethereal oil of juniper.

Toxic parts: Tips of branches.

Toxic action: Meteorism, constipation, gastroenteritis, bloody diarrhea, pharyngitis, laryngitis, tracheitis, abortion, nephritis.

Animals susceptible: Horses, cattle, sheep.

51. **Juniperus virginiana.** Virginia juniper, cedar. Coniferæ.

Poison: Ethereal oils.

Toxic parts: Leaves.

Toxic action: Inflammation of the mucous membrane of the digestive tract, diminished secretion of milk.

Animals susceptible: Goat.

51b. **Lactarius.** See No. 9.

52. **Lathyrus cicer (s. Cicer arietinum).** Everlasting pea or chick-pea. **Lathyrus sativus** or chickling vetch. **Lathyrus clymenum** or black Italian vetch. Papilionaceæ.

Poison: Unknown—volatile alkaloid (Astier), toxicity destroyed by high temperatures.

Toxic parts: Seeds.

Toxic action: Lathyrismus; resorptive, stimulation (excitement, fear) followed by paralyzing effects (weakness in lumbar region, swaying gait, paralysis of vagus and recurrent nerve).

Animals susceptible: Horses (1 to 2 lbs. per day with 10 to 12 lbs. of oats cause violent intoxication in horses), sheep, swine; less toxic for cattle. Cattle not affected by small quantities mixed with other feed (Bayne). Experimental feeding of **L. sativus,** 3 to 4 kg. daily, or 136 kg. in the course of 30 days, produced slight muscular trembling and stiffness in hock.

53. **Linum catharticum.** Mountain flax. Linaceæ.

Poison: Glucosid—linin.

Toxic parts: Tops.

Toxic action: Gastroenteritis.
Animals susceptible: Horses.

54. **Linum usitatissimum.** Common flax. Linaceæ.
Poison: Active narcotic poison and glucosid, forming linamarin.
Toxic parts: Tops (in certain conditions of disturbed development).
Toxic action: Convulsions.
Animals susceptible: Cattle, sheep.

55. **Lolium temulentum.** Bearded darnel or furrow weed. Gramineæ. (Beards projecting beyond the spikes.)
Poison: Glucosid—loliin. Alkaloid—temulin.
Toxic parts: Grain covered with fungous hyphæ (ergot?). Grain free from these is harmless (Hannig, Vogl, Neubauer).
Toxic action: Vertigo, stupor, dullness, anesthesia, mydriasis, cerebritis (sheep), colic, convulsions. Postmortem—Mild gastroenteritis.
Animals susceptible: Horses, cattle.

56. **Melampyrum pratense**, etc. Cow wheat. Scrophulariaceæ.
Poison: Glucosid—rhinanthin.
Toxic parts: Seed.
Toxic action: Enteritis (colic and paralysis), weakness of hind parts, palpitation, hematuria, death.
Animals susceptible: Horses, sheep, rabbits.

57. **Mercurialis perennis** and **M. annua.** Perennial or dog's mercury and annual mercury. Euphorbiaceæ.
Poison: Active purging substance—mercurialin, also methylamin, trimethylamin and an etherial oil.
Toxic parts: Tops.
Toxic action: Exhaustion, fever, icterus, hemoglominemia, hematuria; in severe cases cardiac weakness, anorexia, paresis of rumen, nephritis, bloody milk, paraplegia and even death. Postmortem: Gastroenteritis, nephritis.
Animals susceptible: Horses, cattle, sheep, goats, swine, rabbits.

58. **Myrrhis temula s. Chærophyllum temulum.** Chervil. Umbelliferæ.
Poison: Active narcotic poison—chærophyllin.
Toxic parts: Tops.
Toxic action: Gastroenteritis, tympanitis, paraplegia.
Animals susceptible: Horses, cattle, swine.

59. **Narcissus pseudonarcissus** and **N. poeticus.** Yellow and white narcissus. Amaryllidaceæ.
Poison: Alkaloid—narcitin.
Toxic parts: Tops and bulbs.
Toxic action: Gastroenteritis, dullness, weakness, convulsions, mydriasis.
Animals susceptible: Cattle, goats, swine.

59b. **Nardus stricta.** Fin's grass, (mat grass). Gramineæ.
Poison: Absence of vitamins (fungus infection?).
Toxic parts: Chlorophyl-bearing parts of the plant in the fall of the year; also in the form of hay.
Toxic action: Colic, tympanitis, diminished secretion of urine, constipation, debility, reeling, cyanosis. Postmortem: Hemorrhages in mucous membrane of stomach.
Animals susceptible: Horses.

60. **Narthecium ossifragum.** (Spike lily). Liliaceæ. (Peat bogs and heath land of northern Germany.)
Poison: Glucosid—narthecin.
Animals susceptible: Cattle.

61. **Nerium oleander.** Oleander. Apocynaceæ.
Poison: Glucosids—oleandrin and nerin.
Toxic parts: Especially the bark, also the wood and leaves, flowers less so.
Toxic action: Same as **Digitalis**, glucosids, No. 39.
Animals susceptible: Horses, cattle, sheep, goats, geese. (15 to 25 gm. of the leaves fatal for horse or ox, 1 to 5 gm. fatal for sheep—Wilson.)

62. **Nicotiana tabacum, N. latissima, N. rustica.** Tobacco. Solanaceæ.
Poison: Nicotin (1 to 8 per cent of the dried leaves).

Toxic parts: Entire plant, especially the leaves.
Toxic action: Restlessness, trembling, dyspnea, convulsions, paralysis, contraction of pupils, irritation of digestive tract.
Animals susceptible: Cattle, goats.

63. **Œnanthe crocata** and **Œ. fistulosa.** Water-drop wort, dead tongue, hemlock. Umbelliferæ. (In gardens only, in Germany); wild in swampy places in Austria, Netherlands, France, and England.
Poison: Œnanthin.
Poisonous: Roots especially, tops less so.
Toxic action: Same as **Conium maculatum.**
Animals susceptible: Horses, cattle.

64. **Oxalis acetosella.** Wood sorrel. Oxalidaceæ.
Poison: Oxalic acid.
Toxic parts: Tops.
Toxic action: Diarrhea, in sheep, sometimes fatal.
Animals susceptible: Cattle, sheep.

65. **Papaver rhœas** and **P. argemone.** Wild poppy. **Papaver somniferum.** Garden poppy. Papaveraceæ.
Poison: Opium alkaloids, not destroyed by drying (hay).
Toxic parts: Pods or fruit capsules when in flower or partly matured; less toxic before bloom.
Toxic action: Delirium, convulsions, sopor (predominant symptom in horses), enteritis.
Animals susceptible: Horses, cattle, sheep, swine.

66. **Paris quadrifolius.** Truelove, one-berry, Paris. Liliaceæ.
Poison: Paradin.
Toxic parts: Rootstock, leaves, berries.
Toxic action: Vomiting, colic, diarrhea, stupor, convulsions, paralysis.
Animals susceptible: Poultry.

67. **Phaseolus lunatus.** Rangoon, Java or moonbean. Papilionaceæ.
Poison: Glucosid containing Prussic acid.
Toxic parts: Seed.
Toxic action: Prussic acid poisoning.
Animals susceptible: Horses.

68. **Picea excelsa.** Spruce. See **Pinus.**

69. **Pinus silvestris.** Pine. **Abies pectinata.** Fir. **Picea excelsa.** Spruce. Coniferæ.
Poison: Ethereal oils. Toxicity can hardly be considered as pronounced. Former reports probably based on confusion with piroplasmosis. In the Alpine regions of Austria the thoroughly dried needles are fed in powdered state as an auxiliary feed to sheep and cattle. This is a common practice.
Toxic parts: Needles and bark.
Toxic action: Irritation and inflammation of the digestive apparatus and kidneys.
Animals susceptible: Horses, goats.

70. **Polygonatum multiflorum.** Solomon's seal. Polygonaceæ.
Poison: Convallarin.
Toxic parts: Tops.
Toxic action: Symptoms of digitalis poisoning (see No. 39).
Animals susceptible: Horses.

71. **Polygonatum persicaria.** Peach-leaved knot-weed. Polygonaceæ.
Poison: Polygoninic acid (?)
Toxic parts: Seeds.
Toxic action: Gastritis and cystitis, dullness, convulsions, weakness, paralysis (Dammann). (According to other authors, no hematuria, no cystitis, no gastroenteritis.)
Animals susceptible: Swine, sheep.

72. **Populus balsamifera.** Cottonwood. Salicaceæ.
Toxic parts: Leaves.
Toxic action: Colic, diarrhea.

73. **Prunus domestica.** Plum. **Prunus cerasus** and **P. avium.** Cherry. Amygdalaceæ.
Poison: Same as No. 74.
Toxic parts: Pits.
Toxic action: Same as No. 10.
Animals susceptible: Swine, sheep (prunes).

74. **Prunus laurocerasus.** Wild laurel cherry. **Prunus padus.** Amygdalaceæ.
Poison: Glucosid—laurocerasin (forms Prussic acid).
Toxic parts: Leaves.
Toxic action: Same as No. 10.
Animals susceptible: Sheep (laurel cherry—Dammann), cattle (**P. padus**—Noll).

75. **Pteris aquilina.** Fern brake, bracken. Felicinaceæ.
Poison: Not pteritanic acid (which is identical with felicinic acid) as generally stated in veterinary literature. The former is the toxic principle of **Aspidium filix mas** (male fern). The toxic principle of **Pteris aquilina** is unknown.
Toxic parts: Fronds. 6 lbs. of the dried fronds daily for 30 days are fatal to horses (Hadwen and Bruce).
Toxic action: After feeding on liberal amounts for some time, increased reflex excitability followed by dullness (icterus, dermatitis, necrosis), dilation of pupils, disturbed equilibrium, convulsions and paralysis. Postmortem: Meningitis in the region of the cerebellum and medulla oblongata and general venous congestion.
Animals susceptible: Horses. On the other hand, the rhyzome constitutes a good feed for swine. (Thomas).

76. **Pulsatilla.** Pasqueflower. See **Ranunculus**, No. 77.

77. **Ranunculus sceleratus, R. acer, R. arvensis.** Cursed crowfoot. **Anemone s. Pulsatilla pulsatilla** and **P. pratensis. Pasqueflower.** Ranunculaceæ.
Poison: Anemonol (anemone camphor, mostly lost by evaporation in process of drying, completely evaporated by scalding or cooking).
Toxic parts: Tops.
Toxic action: Inflammation of the digestive tract (salivation, nausea, colic), nephritis, convulsions, stupor.
Animals susceptible: Horses, cattle, sheep.

78. **Raphanus raphanistrum.** Wild radish. Cruciferæ. Controlled by spraying grain fields with 15-20 per cent solutions of sulphate of iron (copperas) on dry days in stage where young weeds have developed the third or fourth leaflet (not to be practiced on crops like potatoes, turnips, beans, vetches, clover, serradella and lupines). The amount of spraying solution required for one hectare (about 2½ acres) is prepared by dissolving and thoroughly mixing 100 kg. of sulphate of iron in 600 liters of water. Applied with special spraying apparatus. Wild radish may also be destroyed by spraying with calcium nitrid (160 kg. per hectare) or finely ground kainite (600 kg. per hectare) or a mixture of both. This serves also as a fertilizer. Common salt (500 kg. per hectare) is also recommended. The latter materials are to be applied in the dry state on bright days when the plants are wet with dew or from recent rain. Kainite also destroys field mustard and most other weeds.
Poison: Possibly same as under No. 85.
Toxic parts: Husks, roots.
Toxic action: Same as under No. 85.
Animals susceptible: Horses.

79. **Raphanus sativus.** Garden radish. Cruciferæ.
Poison: As above.
Toxic parts: Roots and husks.
Toxic action: As above.
Animals susceptible: Horses.

80. **Rhododendron ferrugineum, R. hirsutum,** etc. Rhododendron. Rhodoraceæ.
Poison: Andromedotoxin, also arbutin, ericolin, urson, tannin, gallic acid, resin and ethereal oil.

Toxic parts: Leaves, green or dried.
Toxic action: Salivation, vomiting, gnashing of teeth, constipation, rectal hemorrhages, hemorrhagic gastroenteritis, stupor, cerebritis (sheep). Postmortem—hemorrhagic gastritis.
Animals susceptible: Horses, cattle, sheep, goats.

81. **Robinia pseudacacia.** Yellow locust. Papilionaceæ.
Poison: Robin.
Toxic parts: Bark and blossoms. The leaves alone when fed to bulls, working oxen and sheep were found to be harmless (Fischmann).
Toxic action: Local—inflammatory (gastroenteritis colic). Systemic—irritant, followed by dullness, cardiac weakness, diaphragmatic spasm, diaphoresis. Postmortem—Inflammation of the bowels, parenchymatous degeneration of the liver, kidneys and heart. Blood tarlike.
Animals susceptible: Horses. Sheep and goats seem to resist the toxic action.

82. **Rumex acetosa** and **R. acetosella.** Dock, sorrel. Polygonaceæ.
Poison: Oxalic acid salts (especially calcium).
Toxic parts: Tops.
Toxic action: Diarrhea, gastroenteritis, paralysis.
Animals susceptible: Horses, cattle, sheep.

83. **Russula, etc.** See **Amanita,** No. 9.

84. **Sabina sabina.** See **Juniper.**

84b. **Scleroderma vulgare.** See No. 9.

85. **Sinapis arvensis, S. alba, S. nigra.** Field mustard, white mustard, black mustard. Cruciferæ. (For control, see **Raphanus,** No. 78.)
Poison: Calcium myrosinate (basis of oil of mustard).
Toxic parts: Seed and tops.
Toxic action: Inflammation of the mucous membrane of the digestive tract (salivation, colic, diarrhea), death.
Animals susceptible: Horses, cattle, sheep, swine.

86. **Sium latifolium.** Water parsnip. Umbelliferæ.
Poison: Stated to be an active narcotic substance.
Toxic parts: Roots, after the middle of the month of August.
Toxic action: Convulsions.
Animals susceptible: Cattle.

87. **Solanum nigrum** and **S. dulcamara.** Black nightshade and bittersweet. Solanaceæ.
Poison: Glucosid—solanin.
Toxic parts: Tops.
Toxic action: Stupor, weakness in lumbar region, paralysis of voluntary and cardiac muscles, anorexia, constipation and hemoglobinuria.
Animals susceptible: Horses, cattle, swine, goats.

88. **Sophoro japonica.** Japanese sophora. Papilionaceæ. (Resembles the locust.)
Toxic parts: All parts, even the wood.
Toxic action: Local—irritant.
Animals susceptible: Horses.

89. **Tanacetum vulgare, T. balsamita, T. parthenium.** Tansy. Compositæ.
Poison: Camphor, tanaceton.
Toxic action: Excitability (in rabbits).
Animals susceptible: Cattle. (According to Zink, **T. vulgare** is almost harmless, causing only polyuria.)

90. **Taxus baccata.** Common yew. Coniferæ.
Poison: Alkaloid—taxin, formic acid and irritant resin.
Toxic parts: Fruits, leaves, bark.
Toxic action: Excitement (bellowing), loss of consciousness (convulsion), salivation (cattle), vomiting (swine), tympanitis (goat), frequent urination (horse), convulsions, gastroenteritis, tetanic spasms, paralysis of the respiratory muscles. Postmortem—Hemorrhages in the serosæ, enlarged spleen, tar-like blood, gastroenteritis.
Animals susceptible: Horses (110 to 130 gm. of the needles cause death), mules, cattle (500 gm. fatal), goats, swine (80 gm. fatal), ducks, geese,

poultry (40 gm. fatal), pheasants, deer (100 gm. fatal). It has been observed that cattle, goats and game become habituated.

91. **Veratrum album.** White hellebore. Colchicaceæ.
   Poison: Several alkaloids (veratrin, protoveratrin, jervin).
   Toxic parts: Rootstock, leaves less so.
   Toxic action: Temporary excitement and dullness, salivation, vomiting, tympanitis, diarrhea (often bloody), colic, dyspnea, irregular pulse, spasms, paralysis.
   Animals susceptible: Horses, cattle (180 gm. of dried rootstocks fatal) swine (15 gm.), ducks, chicks.
92. **Vincetoxicum,** Celandine, Swallow-wort. See **Cynanchum,** No. 32.

B. Diseases and Contaminations of Forage Plants

Diseases of forage plants may be brought about by a number of different causes. Important in this respect are the following: (1) vegetable parasites (fungi), the cause of rust, mildew, etc., of plants; (2) injurious animal parasites; (3) weather and soil conditions.

The scope of veterinary hygiene does not include a detailed study of plant pathology, the causes of all plant diseases, nor the remedies for their treatment and prevention. The subject is necessarily limited to the study of those plant diseases, their causes and control, which by their presence in or on forage plants may produce disease or injury in domestic animals, or be suspected in this respect.

I. Fungus Infection (or Diseases) of Forage Plants

The term "fungus infection" is applied to any infectious disease of forage plants caused by specific pathogenic eumycetes such as rust, blight, ergot, dry rot of potatoes, mildew, etc. Such infections interfere with the healthy growth of the plant and impair its feeding value. Some of these parasitic fungi when ingested by animals cause disease in the latter. The effects may be due to the presence of toxins, as in ergot, or perhaps in other cases to mechanical injury of the animal tissues, by the projection of mycelia into the latter, and resulting inflammation. Certain forms or species of pathogenic fungi merely destroy or kill the host plant and thus induce the growth and development of decomposition bacteria, which find a suitable soil in the dead tissues and produce toxic products of decomposition. Finally there exist pathogenic fungi which attack plants but seem to be harmless so far as any effect upon the health of animals is concerned. It is thus seen that the effects of these fungi are of such varied nature that they can not be discussed in general terms.

Parasitic fungi affecting plants form a growth either on the epidermis—epiphytes—or between the cells (intercellular spaces) and within the cells of the host plant—endophytes.

From a hygienic point of view the following are the most important parasitic fungi affecting forage plants:

1. Phytophthora (Peronospora) Infestans, Cause of Potato Disease or Dry Rot of Potatoes

This fungus forms a network of branching threads (mycelium, **m**) between the cells of the potato (Fig. 50). The affected parts of the potato decay, shrivel and become brown in color. Compared with the healthy tissue these parts are of a softer, more elastic or even of a crumbly or cork-like consistency (dry rot) (Fig. 51). The disease is recognizable with the naked eye, externally or on the cut

Fig. 50. Section of potato affected with Phytophthora (x150), *m*, Mycelium; *f*, fruit hyphæ or conidia.

surface. The mycelium of the fungus gradually permeates the entire tuber and spreads to and attacks adjacent potatoes. The disease spreads rapidly when aided by a damp, warm atmosphere. The affected parts of the potato are readily attacked by putrefactive bacteria (Fusaria, *Bacterium phytophthorus,* etc.) and in the presence of a moist atmosphere convert them into a smeary, ill-smelling mass (wet rot). In dry storage, saprophytic mold fungi frequently make their appearance as a white cushion-like mass which later assumes a yellowish, cinnamon or bluish color (*Fusisporium solani, Acrosta-*

lagmus cinnabarinus). These molds are in no way connected with the cause of dry rot. They are true saprophytes.

Course of development of Phytophthora. The **Phytophthora** passes the win-winter in the seed potato. In the spring of the year when the potato begins to sprout, forming stems, leaves, etc., the **phytophthora** forces its mycelium, which is from 3 to 4 microns in diameter, through the stems into the leaves. On the under side of the leaf the hyphæ grow through the stomata or pores (Fig. 52) and form branching fruit hyphæ at the tips of which are formed sporangia or spore sacs, 27 microns long and oval in form (Fig. 53). In the latter are enclosed from 6 to 16 swarm spores, each provided with two long cilia (Fig. 54). The swarm spores dissolve the sporangia at the crown and escape, when they are carried by air currents to healthy leaves or are washed down by the rain and settle on fresh tubers. Within half an hour after swarm-

Fig. 51. Dry Rot of Potatoes.

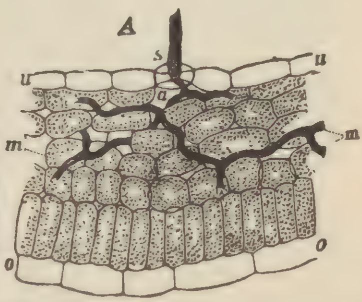


Fig. 52. Section of diseased potato leaf with *Phytophthora infestans* (x 170). Lower surface, *u*; mycelium, *m*; upper surface, *o*.

ing, if placed in water, they become globular and surrounded with a cell membrane, then germinate and penetrate the leaves, stems and tubers, as the case may be, and develop into a network of mycelium. Newly formed arborescent hyphæ capped with sporangia containing swarm spores penetrate to the exterior on the leaf surfaces and complete the cycle of development. Favored by moist warm weather, the disease makes rapid progress and in a short time large areas of a field become infected.

The affected potato leaves (Fig. 55, **k**) are covered with yellow spots which in time become brown and shrunken and which, upon careful inspection of the under side, reveal a white, downy circumvallation. These spots multiply and enlarge in extent, appear on the stalks and branches, until finally the entire plant becomes dark brown in color and dies. Depending upon weather conditions, the affected tops either dry up or decompose, in the latter case producing a disagreeable odor.

Hygienic Importance.—In a number of instances bad effects have been observed following the feeding of infected potato tops. Pota-

toes affected with dry rot are said to cause constipation in young pigs. As a rule, however, they are harmless when fed either cooked or raw. Potatoes affected with wet rot occasionally cause serious indigestion and gastroenteritis. On the other hand, wet rot caused by *Bacterium phytophthorus,* according to Appel and Koske, is rather harmless.

Prophylaxis.—Best possible seed and tillage and the planting of rot-resisting varieties of potatoes. If possible, the crop should be harvested in dry weather; infected or "suspicious" specimens should be carefully removed and the crop stored in a dry, well-ventilated place. Potatoes affected with dry rot should be fed as soon as possible (with addition of salt) or be disposed of for starch manufacturing, distilling or drying. The waste products may be utilized for feeding purposes. Dammann suggests that potatoes affected with dry rot be ensilaged in pits, but this method does not seem practicable to the author. Somewhat greater caution must be observed in the feeding of potatoes affected with wet rot.

2. Peronospora.

Peronospora parasitica frequently affects various Cruciferæ (mustard, rape, Camelina sativa, cabbage, radish). The affected leaves shrivel and become speckled with yellow spots and the lower face becomes covered with a grayish white frost-like down (fruit hyphæ). The terminal branches of the fruit hyphæ are hook-shaped, the conidia almost round, with colorless membrane.

Peronospora viciæ (false mildew). Occurs on various species of vetches, especially the common vetch, **(Vicia sativa)**, lentils, peas and field peas. It causes whitish green scabby spots on the lower face of the leaves. Upon microscopic examination these spots are found to consist of crowded fruit hyphæ with 6 to 8 furcated spreading branches. The terminal branches are short, straight, subulated, the conidia (sporangia) elliptical, whitish violet. Reproduction is asexual, sometimes sexual. The oöspores in the latter form have a thick, retiform, pale yellowish brown epispore.

Hygienic Importance.—**Peronospora viciæ** is said to cause abortion in advanced stages of pregnancy.

Peronospora trifoliorum (false mildew). Parasitic on several species of **Trifolium, Melilotus, Medicago sativa,** etc. The affected leaves become yellow. The fruit hyphæ are several times dichotomously branched, terminal branches subulated, slightly bent; conidia whitish violet, oöspores bright brown.

Besides the species of **Peronospora** mentioned, over fifty others are known which live parasitically upon various forage and garden plants and vegetables. Nothing is known of their pathogenicity to animals.

3. Ustilagineæ. Smut Fungi.

These derive their name from the sooty appearance of the affected parts of the plants (spores, Fig. 56, 1, 3, 5). The Ustilaginæ are all parasitic and attack primarily the flowering parts (or fruit) of plants, although some species affect the leaves and stems, rarely the roots **(Ustilago hypogæa).**

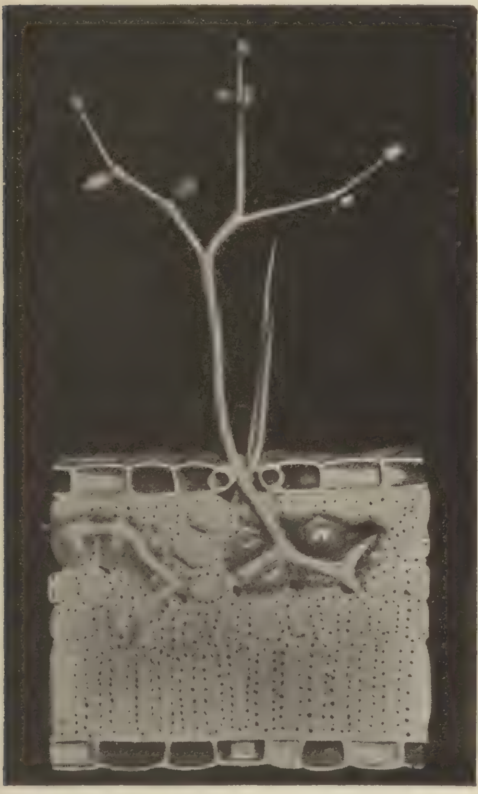


Fig. 53. Arborescent vertical hyphæ with sporangia (x 200). (Brendel.)

Fig. 54. *Phythophthora infestans.* Above sporangum. Middle, ciliated spores. Below, spores penetrating leaf

Development. The mycelium of the Ustilagineæ consists of thick-walled, jointed and branching hyphæ which are generally of very irregular shape. The hyphæ grow in the intercellular spaces as well as in the cell cavities of their hosts. They send out fruit hyphæ with constricted globular ends. These latter constitute the immature, still soft, colorless spores. Upon maturing the latter are converted into a dark, dry, dusty mass (smut). The spores are at first inclosed in the tissues of the host plant. In the further course of development of many species of smut fungi the inclosing tissues burst and the affected part then seems to have been entirely converted into "smut." The spores themselves are very resistant structures and retain their germinating power for two or three years.

When germinating (Fig. 57, 2, 4, 6) the spore sends out a filament (promycelium) which by a process of constriction produces secondary spores (sporidia). The sporidia become detached from the promycelium. They repre-

sent a second generation of germinating elements or spores, since when placed upon a moist surface, they may at once send out filaments and form another set of secondary spores (or sporidia). If, however, the primary filaments

Fig. 55. Potato leaf affected with Phytophthora. *k*, Diseased areas.

lodge on susceptible host plants, they produce mycelium. According to Kuehn, Hoffman, Wolff and others, the penetration of the spore filaments always takes place between the root and the first node of the stem of the young susceptible

Fig. 56. *1-2, Ustilago hordei.* *1*, Habitus; *2*, germinating spore; *3-4, U.nuda; 3*, Habitus; *4*, germinating spore; *5-6*, U.avenae; *5*, Habitus; *6*, germinating spore.

plant. At this stage the flowering parts are still enveloped by the lower or first leaves. After gaining entrance to the young stalk the smut fungi grow up toward and into the undeveloped flower cluster and again form spores in the manner described.

For the germination of the spores it is essential that moisture be present. The development of the Ustilagineæ is therefore favored by wet weather, which occurs when the host plants are in the first stages of their development, by damp soil, fields surrounded by mountains or woods (favoring fog and dew formation), etc. Fertilization of the ground has an influence in so far as it results in a permanent increase of the moisture content of the upper layers of the soil. Fertilization with stable manure carries with it the additional possibility of direct infection with the spores. The spores may pass through the digestive tract of animals without being destroyed and while present in the manure not only retain their germinating power but increase in numbers by the formation of sporidia.

The chief source of infection of young crops is found in the smut spores which are attached to the seed. As a prevention, the cultivation of smut-resistant varieties (wheat) is recommended. An additional precautionary measure is found in the treatment of the previously thoroughly cleaned seed (fanning mill) with sulphate of copper solution, formalin, **sublimoform, fusariol, corvin** or **uspulum.** If proper precautions are observed the germinating and growing qualities of seed grain thus treated will not be seriously affected. According to Kuehn, to treat 2.7 hectoliters of seed (about 7.6 bushels) place the same in a vessel (not too shallow) and add sufficient water to cover the top layers of grain about 4 inches. One pound of sulphate of copper should previously be dissolved in the water. The floating black scum (smut spores and smut-infected grain) should be skimmed off. After twelve hours the solution is drained off and the grain washed with water and spread out in a layer about 4 or 5 inches thick, and dried. Grain thus treated with sulphate of copper should not be fed to animals, even after treatment with limewater. It will cause copper poisoning (p. 152). On the other hand, grain treated with 0.25 per cent formalin for 15 to 30 minutes may, after washing, be fed to animals without bad results. After thorough airing and proper storage, grain so treated may even be considered fit for human consumption.

Wheat treated with **uspulum** (phenol-chlorine and mercury compound) or with fusariol may, according to Hansen, be safely used as a partial ration (mixed with other grain) for animals. Since uspulum is a poisonous mercury compound, the author urgently advises against the feeding of grain thus treated. Sulphate of copper and formalin treatment affect the germinating qualities of grain and are not sufficiently effective against **Fusarium** infection (p. 137). Hot water treatment, as formerly practiced, may give good results. This consists in immersing the seed grain for fifteen minutes in water kept at an exact temperature of 54° C. (129.2° F.).

The straw from smut-infected fields always contains many spores. When such straw reaches the manure pile, the spores germinate and multiply but soon perish if they do not lodge on suitable host plants (according to Franck they vegetate for several weeks). However, if spore-infected manure is applied to the fields before the spores are destroyed, they will serve to infect young host plants. It is therefore not advisable to mix badly infected straw with manure (bedding), or, at least, manure thus infected should not be spread upon fields that are intended to be used for the cultivation of susceptible crops, for at least two or three years.

Mature plants are not infected by smut spores that are carried about by the wind in the field. If the spores lodge on the moist soil they will germinate, but in the absence of proper food material (young susceptible plants) soon perish. Some of the spores, however, remain inclosed in the affected grains, and thus, protected from the effects of moisture, retain their germinating power for a long time and may thus infect young susceptible plants of succeeding crops. To guard against such infection, smut-infected fields should not be planted with the same or other susceptible grains for two or three years.

Finally, certain smut fungi that are parasitic on wild grasses may serve to infect cultivated grain fields.

As far as they concern us in this connection, the numerous species of Ustilagineæ may be classified as follows: **Ustilago, Tilletia** and **Urocystis.**

Ustilago (Fig. 56).—Spores make appearance in mature stage, promycelium branching, forms septa and breaks into sporidia.

Tilletia (Fig. 57).—Spores remain inclosed in the seed coat of the infected host plant. The promycelium is represented by a short, thick stem from which proceeds a tuft of about ten slender branches (sporidia). These branches unite laterally in pairs by a kind of conjugation (not sexual, probably) (Fig. 58). These "copulated" pairs drop off, germinate, and may form secondary sporidia.

Urocystis (Fig. 58).—The spores are several-celled. From 1 to 3 large, central, colored, true spore cells are surrounded by a larger number of smaller, colorless, bladder-shaped cells which represent the vestiges of the spiral fruit hyphæ which have become united with the spore cells.

a. Ustilago

Ustilago carbo (loose smut).—This is frequently parasitic on oats, barley, wheat (not rye) and numerous meadow grasses (species of **Avena, Festuca paratensis, Lolium perenne).** As a rule, the entire inflorescence is affected and the spikelets are generally completely destroyed (Fig. 56). The smut (spores) makes its appearance at an early stage and gives the spikes or heads a black appearance. As a rule, nearly all traces of the smut disappear by the time the grain is ready to harvest, only the empty heads remaining.

The spores are globular, smooth, brown in color and 7 to 8 microns in diameter.

Ustilago maydis (corn smut).—Parasitic on corn only. Spore formation takes place in the grains, stems and leaves. The affected parts become enormously enlarged, forming tumors as large as a man's fist (or much larger). After the spores mature, these tumors burst and discharge a black mass. The spores are round, covered with minute prickles, brown in color and 9 to 10 microns in diameter.

Ustilago bromivora.—Produces a black powder in the spikes of various species of **Bromus** which it infests. Panicles and glumes left intact. Spores delicately verrucose or almost smooth, diameter 6 to 10 microns.

Ustilago longissima.—Parasitic on the leaves of **Glyceria fluitans** and **G. spectabilis,** in long, parallel stripes. Smut powder olive brown. Spores round, smooth, pale olive brown; diameter 2.5 microns.

Ustilago carbo in all probability has no hygienic importance. Tubeuf found it harmless in his feeding experiments. Symptoms observed in cattle (salivation, coughing, watering of eyes, mydriasis, paresis of paunch, colic, diarrhea, death after 15 to 18 hours; post-mortem—pharyngitis, laryngitis, pronounced hyperemic areas in small and large intestine, pronounced serous infiltration of the brain) by Wankmueller, Martin and Eckmeyer after feeding on **Ustilago**

carbo were probably due to other causes. As a rule the spores of **U. carbo** disappear before harvest.

Corn smut, according to observations of Albrecht, is not toxic and does not cause abortion,[1] while Pusch reports abortion from its effects in guinea-pigs, Haselbach in cows and bitches, and Hoefels reports intoxication in horses, Grossman in sheep. Among 400 sheep fed on cornstalks affected with **Ustilago,** 29 became seriously sick and 22 of these died. Postmortem showed ecchymoses in serous and mucous membranes and cloudy swelling of the larger glands. The symptoms disappeared with a change of feed. Liskum and Krassawitzky, after feeding the spores of wheat and corn smut to rabbits, guinea-pigs and mice, and one dog, observed hyperemia of the stomach, intestine, lungs, kindeys and brain as well as the presence of numerous spores in the fat capsule of the kidneys and in the tissue of the spleen. According to Rademaker and Fischer, corn smut contains an alkaloid which they named ustilagin.

As to the toxic action of **Ustilago longissima** reports exist which show that cattle, soon after ingestion of the same, broke down with symptoms of accelerated pulse and respiration, reduced temperature, gnashing of teeth and paralysis. In one instance 12 out of 80 animals died. Postmortem showed reddening of conjunctiva, rectum and vaginal mucosa, bloody serous fluid in the peritoneal cavity, subpleural, subepicardial and endocardial hemorrhages, and red spots in the mucous membranes of the stomachs, especially the fourth stomach. According to Erikson, **Ustilago longissima** is toxic in green forage only, not in hay.

To prevent loss or damage from smut fungi all parts of plants in question that are infected with spores should be burned whenever this is possible. Those parts that contain mycelium only are considered harmless. If, for ecomonic or other reasons, infected forage can not be discarded, it should be steamed for several hours before being fed. As far as preventive measures are concerned, the greatest stress should be placed on the extermination of the disease in plants, as already discussed.

b. Tilletia

Tilletia caries (bunt or smut of wheat) usually attacks all the grains in a single spike of wheat or spelt **(Triticum spelta).** The affected spikes show little change externally (Fig. 57) and are therefore not easily recognized in the field. The affected spikes mature later than the normal crop, remaining green or bluish green and upright. The glumes are somewhat spread, the grain is bloated or puffed, thicker and shorter, more nearly round and lighter in weight (floats on water), the shell is grayish brown, thinner, more

[1] Experience in the United States confirms these observations.—Translator.

readily crushed, and the interior, instead of white flour, consists of a black mass, at first smeary, later dry and of a peculiar herring-brine odor (trymethylamine).

The diseased spikes with the intact but infected grains remain standing upright until harvested with the rest of the crop. Finally they find their way into the screenings or, as only too frequently happens, into the finished product of the mill, flour (imparting dark color and disagreeable odor), bran, etc.

Fig. 57. Smut of wheat. 1, diseased spike; 2, healthy spike; 3, smut grains; 4, sound grains; 5, spores of *Tilletia caries;* 6, spores of *T. laevis;* 7, smut spores germinated in water; 8, smut spores germinated in earth, with wreath of slender conjugating hyphæ. 1-4, natural size; 5-8, magnified 400. (Appel.)

The spores (5) are pale brown, round, 18 microns in diameter and with minutely honeycombed or reticulated surface.

Hygienic Importance.—Numerous feeding experiments with cattle, sheep, goats and swine have demonstrated that **Tilletia caries** is harmless, in spite of the large quantities administered, sometimes even with the addition of purgatives. In earlier experiments, on the other hand, Pusch observed that one of two experimental horses

discharged ill-smelling feces; one of six experimental sheep consumed the infected forage reluctantly, had ill-smelling discharges, became emaciated and finally all but refused entirely to consume the smutted wheat. Another sheep became affected with nasal discharge and wheezing respiration. One of two experimental goats refused to eat entirely on some days, drank copiously, had temporary discharges of ill-smelling, soft feces and became emaciated. Three experimental mice died of hemorrhagic gastroenteritis. One of four experimental chickens showed abnormal excitability followed by somnolency. Another died of a bloody enteritis. Two sparrows died of a bloody gastroenteritis. Among pregnant animals (one sheep, one goat, two rabbits and six guinea-pigs) five of the latter aborted. The sixth guinea-pig had received smutted wheat groats that had been cooked for one hour before feeding. The remaining animals developed no ill effects from the administration of the smut-infected wheat.

Pusch also demonstrated that the spores of wheat smut may pass through the digestive tract of horses, cattle, sheep, goats and swine without loss of germinating power. According to Appel and Koske, however, this is only occasionally the case, and according to Steglich, passage through swine destroys 75 per cent of the spores.

On farms, also, smut-infected wheat has evidently been fed on many occasions to small and to large herds without observable serious consequences. In other instances, again, the feeding of smutted grain has been followed by disease which was supposed to be due to the effects of the smut (cf. p. 111). Thus, according to Albrecht, the feeding of wheat chaff badly infected with **Tilletia caries** and to some extent with **Puccinia graminis** and **Pleospora herbarum,** to 51 cattle, resulted in sickness of 8 head and the subsequent death of three (16 per cent). In an experiment one cow received the separated smut only and developed the same symptoms. When the chaff was discontinued the trouble ended. The symptoms observed were as follows: Spasms of the muscles of mastication, weakness with anesthesia in the lumbar region, fever, inflammation of the conjunctiva, mucous membranes of the nose and upper air passages, urgent desire to urinate, tenesmus. Post mortem showed in one case pronounced, in the remaining cases only slight gastroenteritis with small erosions. In one of the cases a swelling one-half inch thick was noted in the mucous membrane at the bifurcation of the bronchi. Other authors report paralysis of the pharynx, bronchitis, glassy vaginal discharge, abortion, bloody serous contents of the peritoneal cavity, endocardial and epicardial hemorrhages, occasionally food inhalation pneumonia (result of paralysis of pharynx).

In another instance, among seven cows, one (14 per cent) became violently ill following ingestion of smutted spelt and rusty barley straw. Furthermore, poisoning resulted from feeding bran which

had a pronounced odor of herring brine and was found by the agricultural-chemical experiment station at Dahme to contain an unusual quantity of smut fungi (**Tilletia caries**). Symptoms were gastroenteritis, weakness of hind quarters and inability to rise. Aside from affections of cattle, similar results have been observed in horses and swine.

To what degree wheat smut may have been the cause of the above-recorded cases of disease is at this time impossible to determine. It may be safely assumed, however, that small quantities of smut spores (which are frequently present in wheat bran) are harmless.

Tilletia lævis.—Parasitic on wheat, like **T. caries.** Differentiated from **T. caries** by its smooth episporium (Fig. 57, 6).

Tilletia secalis (grain smut).—Forms a brown powder with the odor of herring brine, in the grain of rye. Spores large, 20 to 26 microns in diameter, round with heavily reticulated episporium.

Hygienic importance of **T. lævis** is similar to that of **T. caries.**

A few other species of **Tilletia,** in addition to those enumerated, are found on meadow grasses.

c. Urocystis

Urocystis occulta (rye stalk smut).—Of all smut infections of rye, this is the most important because, as a rule, the entire stalk including the barren spike is destroyed by its presence (Fig. 58, 1). Rye stalk smut, however, is not a common disease. In Italy it affects barley also.

The stalks, leaf sheaths, and occasionally the lower half of the spike, are affected by the fungus. It appears in the form of long gray elevated stripes which finally break and discharge a black powder. The stalks split and break down; the spike dries up.

The "conidia" (Fig. 58, 2) are 24 microns in diameter and contain one to three central cells.

The feeding of smut-affected stalks is said to have produced symptoms of poisoning.

Urocystis occurs in several other species of grasses as well as other plants.

4. Uredineæ. Rust fungi

Rust fungi attack the parts of the plant above ground, especially the leaves, petioles and young branches. They develop in the intercellular spaces of the host plant, forming a septated branching mycelium (Fig. 59, **m**). From this mycelium, beneath the epidermis of the leaf, there spring erect and closely crowded fruiting hyphæ, each tipped with a chain of cells (spores). In some species of rust the epidermis of the leaf remains intact over these masses of spores; in others the overlying epidermis ruptures and sets the spores free, which appear as scab-like crusts on the surface of the leaf and pre-

sent the characteristic general symptom of plant rust (Fig. 60). The color of the little scabs on affected plants is determined by the color of the spores. The latter are either yellow, orange, rust red, brown or black.

Fig. 58. Stalk smut of rye caused by *Urocystis occulta*, Rabehnors. 1, Rye plant affected with stalk smut, slightly reduced; 2, spores of Urocystis occulta (x 400.)

Fig. 60. Grass stalk and leaf, affected with rust.

The development or life cycle of the rust fungi is very complicated. This is due to the fact that they produce special summer and winter spores, are generally polymorphic, and each form is parasitic on a different host plant. As already indicated, they produce a branching mycelium (Fig. 59, **m**) in the affected areas of the leaves. During the summer this mycelium sends up fruiting hyphæ (basidia) at the tips of which sopres (usually only one, uredospores or summer spores, Fig. 59, **u**) are formed by a process of constriction. This

spore is one-celled, usually round or elliptical, surrounded by a prickly episporium, reddish yellow, rusty red or brown in color. These spores soon become free. When lodged on suitable host plants they germinate and penetrate the stomata of the leaves and produce mycelium, which in turn produces uredospores as above described. Thus two generations of the rust fungi are developed in the course of a summer, aiding in its dissemination. Later on, when the uredospores have matured and, for the greater part, died off, the same mycelium produces teleuto spores, or winter spores (Fig. 61, **t**), which are quite different from the summer spores or uredospores. They are firmly united with the host plant by means of broad fruit-bearing hypæ (basidia) and remain there through the winter. As soon as conditions become favorable for development the teleuto spores germinate and form a promycelium (Fig. 62, C and D), which sends out short lateral branches tipped with spordia (**sp**). For further development the sporidia must lodge on suitable host plants, which, in the case of many rust fungi, are of a different species from those on which the first stages of development occurred (alternation of hosts, heteroecism). Under such favorable conditions the germinating filaments pierce the epidermis of the leaf and develop into a branching mycelium. The spores are formed in small round circumscribed arears immediately under the epidermis of the under side of the leaf. They occur in terminal chains on short stalks, are orange yellow, single celled, roundish polyhedral in form and usually surrounded by a goblet or

Fig. 59. *Puccinia graminis.* *e*, epidermis; *m*, mycelium; *u*, uredo spores. (x300.)

flask shaped membrane (peridium). By their growth these masses of spore-bearing stalks (æcidia) burst through the epidermis of the leaf and appear on the surface (Fig. 63 **a**, **r**).

Besides the æcidium fruits on the lower or under surface of the leaf there appear on the upper surface flask-shaped forms (Fig. 63, **sp**), spermagonia, which are filled with slender, hairlike filaments. The latter break up into numerous exceedingly small oblong bodies, the spermatia, which are regarded as functionless sex organs.

When the æcidiospores lodge on suitable host plants they germinate and produce mycelium, which gives rise, first to uredospores, then to teleutospores, etc.

Rust fungi that complete their cycle of development on one species of host plant are called **autœcious**; those in which the alternate generations develop on different species of host plants are called **heterœcious.**

The life cycle of all rust fungi is not as complicated as those above outlined. Some of them do not require a change of host plant nor do they form æcidiospores. Others do not produce uredospores, but only teleutospores, the æcidium being either present or absent. Finally, the life cycle of some of these fungi has not as yet been worked out.

Rust diseases are or may be prevented by the extermination of the intermediate host plants (barberry in case of wheat rust), abolishing "fence rows," burning stubble and other waste parts of plants that contain teleuto spores, early sowing of winter as well as spring and summer grains, and the selection of hardy or rust-resisting varieties of seed grain. Thus Squarehead wheat and "Propsteier" rye and "Anderbecker" oats are considered as resistant to yellow rust, though not resistant to striped rust.[1]

Of approximately 70 known species of rust fungi a comparatively few are of interest or importance in this place. They belong to the following groups:

1. **Puccinia.** Produces two-celled teleutospores (Fig. 61, **t**), is always heterœcious, and parasitic mainly on grasses.

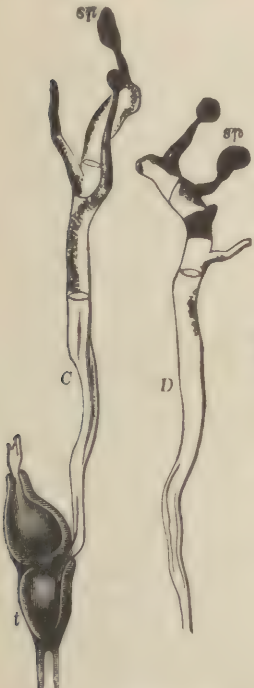


Fig. 62. *Puccinia graminis.* *t*, teleutospore with promycelium. *C.* and *D.* sp., sporidia. (x 600.)

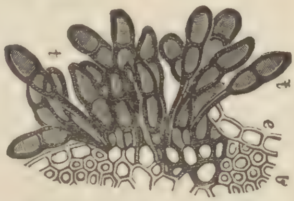


Fig. 61. *Puccinia graminis, e,* epidermis; *t,* teleutospores. (x 300.)

Fig. 63. *Puccinia graminis* or barberry leaf. *e,* epidermis; *a,* æcidium fruit; *h,* pseudoperidium; *r,* chain of spore; *b,* sterigmata; *st,* stromatic foundation on which the spermagonia rest; *sp,* spermagonium with escaping spermatia. (x 60.) (Sorauer.)

2. **Uromyces.** Has one-celled teleutospores (Fig. 66), is usually autœcious, rarely heterœcious, and parasitic mainly on leguminoceæ.

[1] In the United States, Kanred wheat had been found resistant to some forms of stem rust as that found in Kansas, while Kota wheat is resistant to some of the forms of rust found in the spring wheat sections. Acme and Monad wheats are likewise resistant to some forms of rust. Green Russian oats are resistant to crown rust, but no varieties of rye have been found resistant to any of these rusts.—J. R. M.

a. Puccinia

Puccinia graminis.—Common grass or grain rust, leaf or stripe rust. This is the most widely disseminated rust of grain (rye, wheat, barley and oats) and of numerous grasses (**Triticum repens, Lolium perenne, Dactylis glomerata, Agrostis vulgaris**). It is parasitic on all green parts of the plant, but especially on the leaves and sheathes, and appears in the form of little rust-red powdery heaps which burst through the epidermis of the leaf in longitudinal rows parallel with the veins of the leaves.

Fig. 64. Teleutosporea of Crown Rust (x 300.)

The uredospores (Fig. 59) are elliptical, 36 microns long and 18 microns wide. The teleutospores (Fig. 61) which, in the various species of grains, are formed only on the lower leaf, sheathes and joints of the stalk, are obovate in form with rather regularly rounded crown. They have a short basidium, about the length of the spore. The æcidium develops on **Berberis vulgaris** (barberry) in the form of orange yellow spots on an elevated yellow background. To the unaided eye the spermagonia appear as dark points. They discharge a slimy substance containing numerous spermatia.

Puccinia Rubigo vera (s. straminis, Funkel).—Spot rust. This is not infrequently parasitic on rye, wheat, spelt, oats and barley as well as on **Bromus mollis** and **Hordeum murinum,** and appears in the form of small, usually somewhat elongated, spots.

The uredospores are globular; the teleutospores are permanently covered by the epidermis. They are club-shaped, with a short stem, the crown broadly truncated or irregularly pointed. The æcidium stage is found on the leaves of many Asperifoliacæ (**Anchusa officinalis, Borago officinalis, Lycopsis s. Anchusa arvensis, Symphytum officinale,** etc.). They resemble those on the barberry. The æcidium is not absolutely necessary for the continued propagation or preservation of the species.

Puccinia coronata.—Crown rust. This attacks **oats** as well as **Holcus lanatus, Calamagrostis epigea, Aira cæspitosa, Alopecurus pratensis** (foxtail) and **Festuca elatior.**

Uredo stage same as that of **P. rubigo vera.**

Teleutospores (Fig. 64) covered by the epidermis, short stalked, somewhat club-shaped, crowned with several irregular toothed projections. Æcidium thrives on **Rhamnus frangula** (black adler) and **R. catharticus** (buckthorn).

Puccinia arundinacea.—Reed rust. Parasitic on **Phragmites communis s. Arundo phragmites.** Uredospores large, elliptic, brown. Teleutospores elongated, constricted at transverse septum. Aecidium occurs on several species of **Rumex** (dock).

The *hygienic significance of the rust* fungi has not as yet been thoroughly cleared up. While Tubeuf denies the existence of any and all pathogenic properties of rust fungi, Franck observed that the feeding of leaves of **Elymus europæus** (European wild or sand rye) badly infected with **Puccinia graminis** (in the uredospore stage) to rabbits caused on the fourth day disturbance of the sense of equilibrium, tendency to fall or tumble over backward, spasms of the dorsal muscles, mydriasis, retarded pulse and respiration, lowering of temperature and death, showing cystic paralysis at post-mortem. Franck also demonstrated that the uredospores can pass through the intestinal tract without losing their germinating power. Our veterinary literature contains a great number of observations of practicing veterinarians relative to the toxic action of rust fungi, even though a not inconsiderable part of these observations are of no value on account of their inaccuracy.

Poisoning by rust fungi has been observed in horses, cattle, sheep and swine following feeding on infected green forage, hay, straw and reeds. The symptoms enumerated are: Dermatitis of the lips, cheeks, eyelids and other parts of the head; even urticaria with violent itching of the whole body; conjunctivitis; inflammation of the mucous membrane of the mouth, tongue and pharynx, with erosions the size of a bean (socalled sporadic aphthæ, often confused with foot-and-mouth disease); colic, violent and even bloody diarrhea (uredospores of **Puccinia rubigo vera**), nephritis (hematuria), staggering, extreme weakness, palpitation, paraplegia (hind legs and bladder), general paralysis (in cattle, suggesting parturient paresis), dullness, somnolency, fever, abortion, icterus, death.

Postmortem appearances: Hemorrhagic gastritis and enteritis (teleutospores of **Puccinia graminis**), nephritis and cystitis, reddening and swelling of the rectal and vaginal mucous membranes, subserous hemorrhages.

The ingestion of rust-infected forage, however, is by no means always followed by serious effects. There is no doubt whatever that rust-infected forage has frequently been fed without resulting harm (experiments of Tubeuf). According to Giersberg, the feeding of rust-infected straw resulted in disease of young stock only, and sucklings whose dams had received such feed, while the older animals escaped.

The harmful effects of the feeding of rust-infected forage (especially reeds) may be prevented by exercising a little care (destruc-

tion of the infected forage or by resorting to preliminary feeding tests).

It might also be well to ascertain, before attempting to utilize forage of doubtful character, whether cooking or steaming under pressure removed or reduced the danger of feeding to animals. Otherwise the control of rust diseases of forage plants should be attempted along lines already indicated.

b. Uromyces

The **Uromyces** are recognized by their one-celled teleutospores (Fig. 65). They are parasitic principally on the Leguminosæ. The æcidia usually form on the same host plant with the rust colored

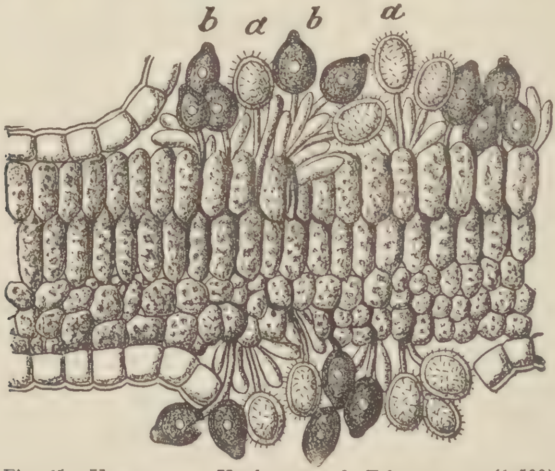


Fig. 65. Uromyces—*a*, Uredospores; *b*, Teleutospores (1:500)

uredospores and the black teleutospores (autœcious). The following species are of interest:

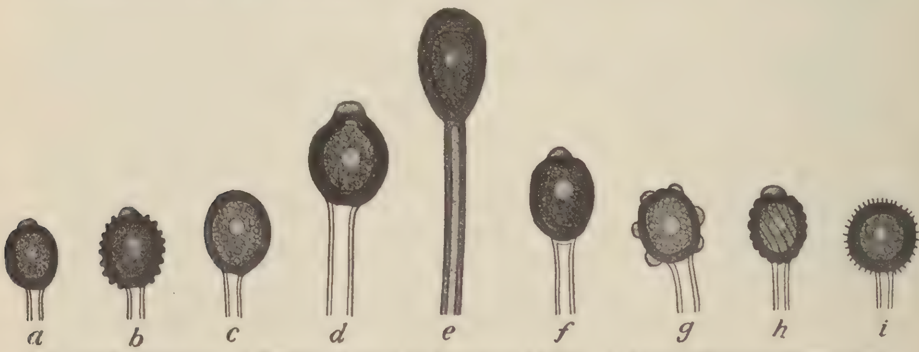


Fig. 66. Teleutospores of different species of *Uromyces* (*x* 500). *a*, *U.astragili* (rust of esparsette-sainfoin); *b*, *U.genistae* (on esparette); *c*, *U.pisi* (pea rust); *d*, *U.appendiculatus* (bean rust); *e*, *U.fabrae* (rust of field bean); *f*, *U.trifolii* (clover rust); *g*, *U.anthyllidis* (rust of kidney vetch, lady's finger and lupine); *h*, *U.striatus* (rust of lucerne, alfalfa, hop trefoil and bird's-foot trefoil; *i*, *U.lupini* (rust of lupines).

Uromyces fabae.—Occurs on species of vetches (**Vicia faba,** broad bean, horse bean, garden bean; **V. sativa,** common vetch; **V. cracca,** tufted vetch; **V. sepium,** bush vetch, etc.) **Ervum s. Lens lens** (lentil) and species of **Lathyrus** (chick-pea). The stem of the teleutospore is longer than the spore, which latter is much enlarged at the crown (Fig. 66-e).

Uromyces apiculatus s. trifolii.—On cultivated clovers (**Tri-folium pratense, T. repens, T. montanum, T. hybridum**); teleutospores loosely attached, enlarged at crown (Fig. 66-f).

Uromyces appendiculatus.—Bean rust. Autœcious, parasitic on **Phaseolus** species (beans). Teleutospores short stemmed, easily detached, with rounded flat knob on crown (Fig. 66-d). Æcidiospores almost white.

Uromyces striatus.—Occurs on species of **Medicago**—(lucerne, alfalfa, hoptrefoil, nonesuch) as well as on **Trifolium arvense, T. Agrarium, Lotus** (bird's-foot trefoil), **Ervum s. Lens lens** (lentil). Teleutospores (Fig. 66-h) short stemmed, easily detached, episporium delicately striated. Æcidium develops on **Euphorbia cyparissias,** thereore heterœcious.

Uromyces anthyllidis and U. lupini.—Occur on lupines. The former occurs also on **Anthyllis** (kidney vetch), **Ononis** (groundfurze or rest-harrow) and **Trigonella.** Æcidia and spermogonia unknown) Fig. 66-g).

Uromyces pisi.—Pea rust. Heterœcious. Æcidia and spermagonia on **Euphorbia cyparissias** and other Euphorbiaceæ. Uredospores and teleutospores on **Pisum sativum** (pea) and species of **Lathyrus** (chick-pea), (Fig. 66-c).

Uromyces astragali and U. Genistæ.—Occurs on esparcet (sainfoin). Æcidia unknown (Fig. 66-a and b).

Uromyces betæ.—Rust of sugar beet and common beet (Chenopodaceæ or goose foot family). Autoecious. Leaves become yellow, then brownish, and die.

For the control of rust in these plants little or nothing can be done except the removal of the diseased parts in the spring of the year and their destruction by burning.

The **hygienic importance** and methods of prevention are the same as for **Puccinia,** which is true also of clinical symptoms of disease (and postmortem changes) caused by these rusts.

5. Erysiphaceæ. Mildew.

The Erysiphaceæ form powdery or webby coatings, whitish or of different colors, on the green parts of the plant, and are known **generically** as mildews (not to be confused with mildews of animal origin, which consist of the cast-off skins of aphids—plant lice).

The mycelium grows on the surface of the epidermis and firmly attaches itself by means of peculiarly formed lateral branches (haustoria or sucking or-

gans) which penetrate the epidermis cells. After making a certain growth, the mycelium produces numerous vertical fruit-bearing or conidia-bearing hyphæ (Fig. 67), at the tips of which spores are formed by a process of constriction. The spores (conidia) are oval, single celled, white, and capable of germinating immediately after becoming detached. In a stage of prolific spore formation, the mildew appears as a rather thick whitish layer. At the termination of the spore-forming stage the numerous perithecia develop. These are round capsules, at first colorless, later becoming black and visible to the unaided eye as minute black points (Fig. 68). Under the microscope (magnified 100 to 400) the perithecia are seen to be surrounded by long appendicula (so-called supporting filaments). The perithecium itself consists of a thin membrane enclosing one or more asci arranged in bunches. The asci each contain from two to eight single-celled, oval, rather thick-walled, colorless or brownish spores (ascospores). These ascospores do not germinate until the following spring. The mildew above described develops from these spores. The young parts of plants that become affected with mildew frequently die; the older parts suffer less injury.

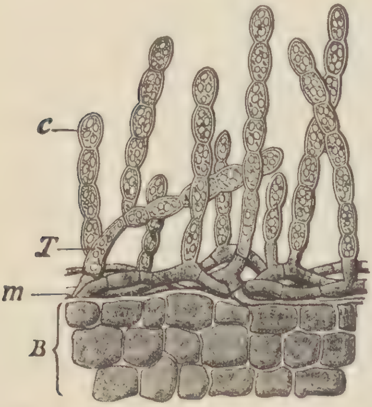


Fig. 67. Mildew, conidial form. *B*, grass leaf; *m*, mycelium; *T*, conidia-bearing hyphæ; *C*, conidia. (x 200.)

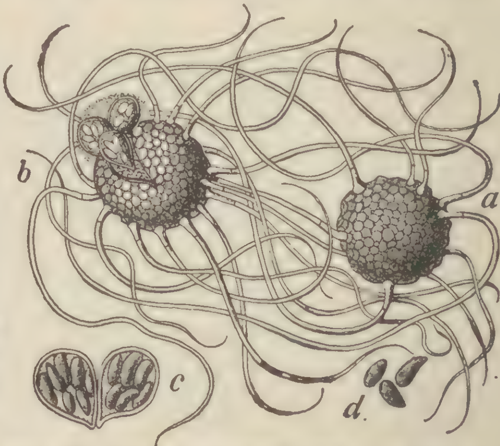


Fig. 68. Mildew, perithecium stage. *a*, closed; *b*, opened perithecium with escaping asci. (x 300.) *c*, two ascospores; *d*, spores (x 400.)

For the control of mildew all plants or parts of plants (straw, etc.) containing perithecia should be destroyed by burning. The application of flowers of sulphur, or an emulsion of lime, 2 parts, and flowers of sulphur, 3 parts, in 5 parts of water, and other remedies, though practicable for garden vegetables and grapes, would hardly be advisable for forage plants.

Of the thirty or more known species of mildew the following only will be mentioned.

Erysiphe martii.—Mildew of alfalfa, **Trifolium incarnatum,** (flesh-colored trefoil, scarlet clover), red clover, field bean, vetch, lupine and **Melilotus** (melilot). Parasitic also on several Umbelliferæ **(Chærophyllum cerefolium, Anthriscus cerefolium** (garden chervil), parsnip, **Heracleum sphondylium** (cow parsnip), **Angelica archangelica** (angelica), **Pimpinella anisum** (anise). Also parasitic on **Urtica** (nettle), **Spireæ** (spirea), and species of **Brassica** (cabbages), etc. This form of mildew often causes great white streaks to appear in clover fields.

Erysiphe communis.—Parasitic on meadow chick-pea, several Ranunculaceæ, Geraneaceæ, Polygonaceæ, etc. The appendiculæ are brown and white and two or three times as long as the perithecia.

Erysiphe graminis.—Occurs on **Dactylis glomerata** (orchard grass, cock's-foot grass), **Poa** (meadow grass, [Kentucky bluegrass, June grass and spear grass]), as well as on all of the grains. The perithecia are half submerged in the cushion-like mycelium, the appendiculæ are colorless, the asci contain 8 spores.

Its hygienic significance has not yet been definitely determined. According to some observations it is the cause of inflammatory conditions of the digestive organs and kidneys as well as abortion and even death in cattle. According to Diem, calcium chlorate is effective in treatment. On the other hand Wolff fed badly mildweed (gray colored) lupines to mast wethers and lambs (3 kg. per head) without injury.

It would, of course, be advisible in all cases to observe caution in the use of badly mildewed forage.

6. The Causes of Leaf-Spot Disease

These organisms, which are arbitrarily grouped together, have this in common, that they are parasitic on leaves, and, starting as single or numerous points or dots, spread out in patches, destroy the neighboring tissues of the leaf, and thus produce brown or black rings or (on some plants) concentric patches.

Fig. 69. Leaf spot disease of clover, caused by *Pseudopeziza trifolii.* Clover leaves with numerous leaf-spots, slightly reduced in size.

Fig. 71. *Pseudopeziza trifolii,* two asci with spores and adjacent paraphyses. (x. 600.)

Pseudopeziza trifolii (Fig. 69-71).—This is the cause of leaf-spot disease on red and white clover. A near variety attacks alfalfa and spreads over entire fields in a comparatively short time. This epiphytic parasite produces goblet-shaped and cup-shaped membranous enclosures (apothecia) in the center of the gradually drying brown to blackish leaf-spots. These apothecia are crowded with vertically placed asci and intermediate filamentous paraphyses (Fig. 71). The asci contain 8 spores, single celled, colorless and longish oval.

Cercospora betæcola.— Leaf-spot disease of the common and sugar beet (Fig. 72). Not infrequently the cause of numerous brown spots on and premature death of, the leaves of beets. Conidia-bearing hyphæ in clusters, nodular at the tips, brownish. Conidia needle-shaped with closely placed septa, colorless, O.1 mm. long and 3 microns in diameter.

Cercospora zonata.—The cause of leaf-spot disease in the field bean. Others parasitic on a number of forage plants.

Fusarium heterosporum.—Attacks several species of grain and is the cause of winter killing of grain.

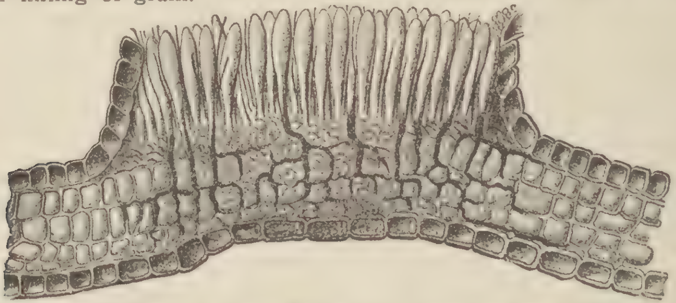


Fig. 70. Leaf-spot disease of clover. Section of a disease portion of the leaf. (150.)

Fig. 72. Leaf-spot disease of beet, caused by *Cercospora betaecola* (Saccardo) (½ natural size.) *b*, section of a disease focus (x 250.); *B*, dead leaf tissue, permeated by mycelium (*m*) of the fungus; *T*, fruiting hyphæ; *C*, conidia.

Glœosporium.—Species of this genus are widely disseminated and are the cause of spots (Brennerflecken—burns) on the leaves and fruits of numerous forage and other plants (e. g., beans). Similar spots are frequently caused by

a number of other species. Since their pathogenicity for domestic animals has not been sufficiently determined, their further discussion may be omitted.

Scolecotrichum graminis.—Botanically related to **Polydesmus exitiosus** (p. 152). It is the cause of leaf-spot disease on French rye grass, timothy or Hoard grass, foxtail (**Alopecurus pratensis**), orchard grass, dog's-tail grass (**Cynosurus cristatus**), **Poa** or meadow grass (bluegrass, etc.), spring grass (**Thoxanthum odoratum**) and manna grass. Before or during the blossom period large areas or the entire leaves become bleached within a short time, then become brownish and dry up. On the bleached portions of the leaves there soon appear numerous exceedingly small dots or points, just visible with the unaided eye. These points are of a deep black color and are sometimes arranged in longitudinal rows. Examined under the microscope, these points resolve themselves into clusters of short, filiform, unbranched, soot-colored fruiting hyphæ, projecting through the epidermis of the leaf. The fruit-bearing hyphæ have terminal or lateral olive brown spores with transverse septa. Spores 35 to 45 microns long and 8 to 10 microns in diameter.

Scolecotrichum hordei.—Parasitic on barley. Fruit-bearing hyphæ and spores light yellow.

Helminthosporium gramineum.—Cause of brown spotting of barley. Striated brown spots appear on the leaves, death of the leaf follows, beginning with red discoloration at the tip. The conidia-bearing hyphæ are brown, the spores yellowish, straight, cylindrical, with one to five transverse septa, 50 to 100 microns long and 14 to 20 microns in diameter.

Phyllachora graminis. Cause of leaf scab of grasses (millet, orchard grass, timothy and brome grass). Elongated, black, slightly shiny, somewhat elevated crusts appear on both sides of the leaf. The thick, felt-like, coarse, black mycelium (stroma) develops in the parenchyma of the leaf, forming plates 1 to 10 mm. in length, in which are embedded white perithecia about 0.3 mm. in diameter. The latter consist of a round capsule containing asci with eight spores each, and filamentous paraphyses. Nothing is known in regard to their pathogenicity for domestic animals.

Phyllachora Trifolii.—Known in veterinary literature almost exclusively as **Sphæria** or **Polythrincium trifolii.** This is the cause of "blackening" of Swedish, red and white clover. Small, round, black spots appear on the under surface of the leaf and on the stems. The perithecia (cf. p. 148) are crowded and project beyond the stroma. The asci are club-shaped, the spores elliptical (10 by 5 microns). Beside these are minute spermatia (cf. p. 142). Spore formation also takes place by constriction of the ends of the clustered conidia-bearing hyphæ. These spores are two-celled, oblong-elliptical, size 24 by 15 microns.

Serious outbreaks of disease have been observed following the feeding of clover affected with **Polythrincium** (stomatitis, pharyngitis, rhinitis, conjunctivitis, dermatitis, gastritis, enteritis, as well as fever, unsteady gait, weakness in lumbar region, general paralysis. The nature of the injurious substance is not known. Schoeberl considers **Polythrincium** in itself as harmless.. He is of the opinion that saprophytes (**Aspergillus** and a bacillus [not yet investigated]) lodge in the dead leaves and produce the injurious effect. To prevent the serious consequences attending the feeding of "blackened" clover, Kuehn recommends sowing grasses with clover, which materially checks the spread of clover disease. Schoeberl is of the opinion that the development of the saprophytic fungi referred to can be checked

or diminished by pressing the green forage (see Klimmer, The Scientific Feeding of Animals) and thus its harmfulness averted.

Polydesmus exitiosus.—Rape destroyer. Affects all green parts and particularly the green husks of rapes and turnips, also potato tops (leaf roll) and various weeds. In June (or later in summer crops) small blackish green or brownish black spots make their appearance. The surrounding tissue at first remains green but finally dries up and yellows or becomes reddish. The tuber crop may be entirely destroyed.

Polydesmus (Fig. 73) forms a delicate, colorless, branching mycelium between the cells in the parenchyma of the host plant. Immediately under the

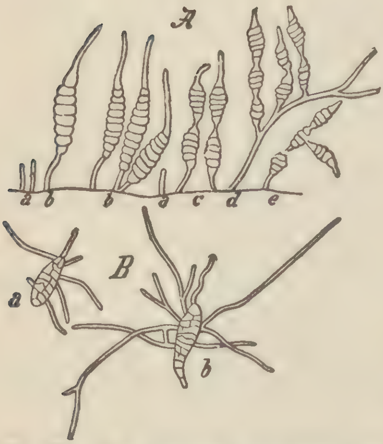


Fig. 73. Rape destroyer, *polydesmus exitiosus.* A, different forms of spores; B, germinating spores.

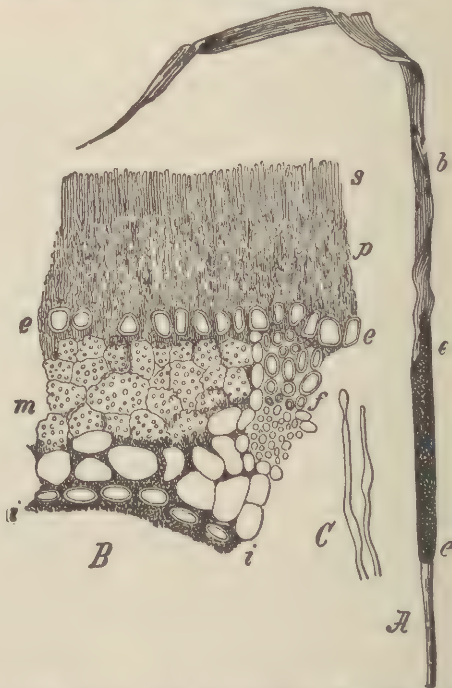


Fig. 74. *Epichloe typhina. A,* culm with *Epichloe typhina* (*ee*) natural size. *B,* section of diseased sheath; *ii,* epidermis of inner surface; *ee,* the same on outer surface; *m,* parenchyma of leaf filled with mycelium; *f,* fibro-vascular bundles; *p,* fungus tissue with fruiting hyphæ; *s.* (x 150); *c,* two fruiting hyphæ (x 600).

epidermis the hyphæ are larger and more densely disposed, a few of the hyphæ breaking through the epidermis and developing unbranched conidia-bearing basidia. The basidia or fruiting hyphæ become septated transversely, brown in color, and by constriction form a spore at the tip. The latter is at first round, then oval and finally spindle-shaped. The spore then becomes transversely septated. It terminates in a short, slender filament which may continue to grow and form a second spore in the same manner, and sometimes a third. The ripe spores are easily detached and, under favorable conditions, germinate rapidly and develop into the above-described mycelium. In damp, warm weather the disease may spread to a considerable extent in the course of a few days.

Hygienic importance.—The feeding of affected rape, turnips or potato tops, or pasturing on rape stubble, may produce intense local ulcerous inflammations (of the skin, mucous membranes of the digestive tract, nose and eyes) as well as weakness and symptoms of paralysis, especially of the hind legs. According to investigations of Berndt, it may be assumed that the spores which lodge on the nasal and buccal mucous membrane pierce the latter with their promycelia.

As a preventive measure it is suggested that stubble be not pastured until after a rain, thus permitting the spores to be washed from the vegetation. Affected husks, straw or potato tops should be steamed before feeding or before being used as litter. If for economic or other reasons affected material is used as litter, the manure produced therefrom should not be spread on fields that are intended for the cultivation of crops susceptible to **Polydesmus.** The best plan is not to use affected straw, etc., at all, but to destroy it by burning.

7. Epichloe typhina. Cat-tail fungus

The fungus **Epichloe typhina** is parasitic on **Phleum pratense** (timothy), **Dactylis glomerata** (orchard grass), **Poa nemoralis** (meadow grass), **Holcus lanatus** (German honey grass), **Agrostis vulgaris** (bent grass), **Brachypodium sylvaticum,** etc.

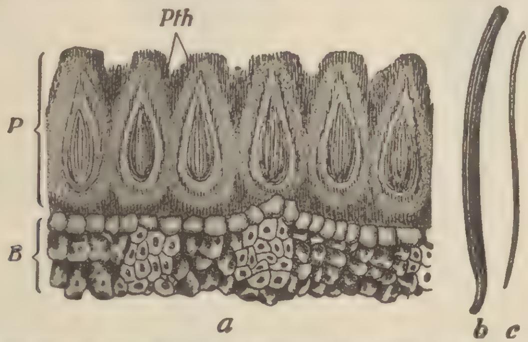


Fig. 75. *Epichloe typhina.* *a,* section of leaf sheath; (*B*), above this, fungus tissue (*P*), with perithecia (*Pth*) (x 100); *b,* spore sac (x 300); *c,* spore.

Before the grasses are in bloom it forms a white coat or covering which gradually increases in thickness, becoming golden yellow and finally reddish brown, around the uppermost leaf sheath which still incloses the younger leaves. After the uppermost leaf has dropped off the fungus resembles a small reed mace, whence the name typhina. The length of the fungus mass varies according to the species affected, between 1 and 9 cm, the diameter between 2 and 4 mm.

Epichloe (Fig. 74) forms a mycelium between the cells of the tissues of the host, breaks through the epidermis and then produces a fleshy, white, felt-like mass on the surface. This felt-like mass increases in thickness; the closely packed, mostly radially disposed, branching filaments form minute spores at their tips by a process of constriction. After the production of conidia has ceased, innumerable small, oval, yellowish, soft perithecia appear (Fig. 75, **Pth**), giving the body of the fungus mass a sprinkled appearance and transforming its white color into a golden yellow. The perithecia contain numerous asci, up to 2 mm. in length (**b**) and each of the latter contain 8 colorless, filamentous spores (**c**) which mature on the plant in the course of the summer.

Fig. 76. Head or spikelet of rye with ergot (slightly reduced).

Fig. 77. Ripe ergot with cap (slightly enlarged).

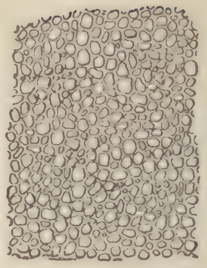


Fig. 78. Cross section of sclerotium, freed from fat (x 800).

Fig. 79. *A*, healthy ovary; *B*, ovary infected with ergot of rye; *s*, body of fungus, sphacelia.

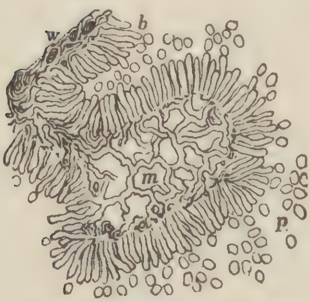


Fig. 80. Sphacelia (cross section). *m*, mycelium; *b*, fruit-bearing hyphæ; *p*, spores. (x 600.)

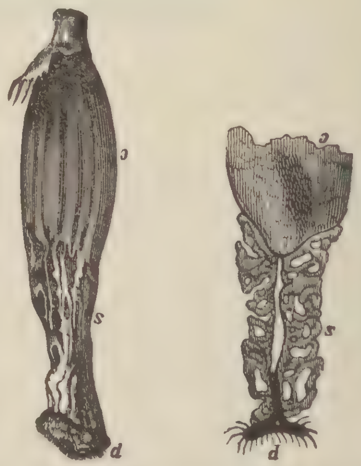


Fig. 81. Metamorphosis of the spacelia into ergot. *A*, external view; *B*, cross section; *p*, vestige of ovary; *s*, sphacelia; *c*, sclerotium (enlarged).

Hygienic importance.—According to a feeding experiment with a rabbit by Franck, with **Epichloe typhina** in the white stage (on **Poa pratensis**), gangrene developed on all feet on the 4th day. Death followed five days later. Postmortem examination showed spotted red areas in the lungs, and hydrocephalus. No reports from veterinary practitioners are available.

8. Secale cornutum. Ergot

Ergot, **Secale cornutum,** (Figs. 76 and 77), occurs in the form of slightly curved, black, cylindrical growths (spurs) with minute shallow, longitudinal furrows. The inner tissue is white, hard and brittle.

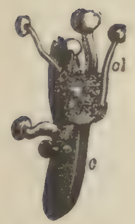


Fig. 82. *c,* Sclerotium with germinated capitula; *cl,* Claviceps purpurea. (Natural size.)

Fig. 83. Longitudinal section of capitulum with embedded perithecia, *cp.* (x 15.)

Fig. 84. Two perithecia. *cp,* closed perithecium; *sh,* open, showing asci; *sp,* ascus with germinating spores. (x 200.)

It develops in the place and position of the ovary or grain (which it destroys), and is found on most grasses, like rye, wheat, barley, oats, **Lolium, Poa, Nardus, Glyceria, Bromus,** etc., even on so-called sour grasses. The spurs are about twice as long as the floral glumes and on rye attain a length of 1 to 3½ cm., on **Lolium perenne** 6 to 8 mm., and on **Poa annua** 3 mm. A single inflorescence (head or spike) frequently contains but one or two spurs (Fig. 76). The ergot represents the hardened tissue (sclerotium) of the ergot fungus (Fig. 78).

If the spores of this fungus lodge on the ovary of blooming grasses, they develop beneath the former. The infected ovary, instead of its normal globular form (Fig. 79, A) assumes a cylindrical form (B). The cheesy, white mass of mycelium continues to develop at the expense of the host, pushing the stunted ovary upward in its course. This mass, which represents the first (or sphacelia) stage in the development of the ergot, consists interiorly of loosely interwoven mycelium (Fig. 80), which becomes denser near the surface, forming numerous winding furrows and producing on its surface short, densely placed, vertical fruit-bearing hyphæ (basidia), at the tips of which spores are formed by a process of constriction. Formerly this stage of development was looked upon as a distinct fungus **(Sphacelia segetum).** During sporulation the hymenium (the basidia-bearing surface) excretes a sweet, sticky fluid (honey

dew) of a milky appearance due to an admixture of spores. This fluid oozes out between the glumes. The spores are disseminated through the agency of insects, which feed greedily upon the honey dew, also by the action of rain and by direct contact of the spikes. When the spores lodge on blooming Gramineæ, they immediately germinate and their further development proceeds in the manner described.

When sporulation terminates the sphacelia become transformed into "ergot" (Fig. 81, A, B). The mycelium multiplies and becomes intricately woven into a firm, hard, solid tissue, consisting of roundish polygonal cells with rather thick membranes and contents rich in oil (Fig. 78). The superficial cells become blackish violet, the interior cells remain white or colorless. These changes begin at the base and gradually extend upward toward the free end, without, however, transforming the entire sphacelia into ergot; the rest of the sphacelia dries up and forms a little cap on the tip of the ergot (Fig. 77). The longitudinal growth of the ergot proceeds from the base and finally forces itself beyond the glumes. At this stage it is readily detached and usually falls to the ground at harvest time.

In the following spring, in contact with moist ground, minute white papillæ appear on the ergot, which develop into pedunculated capitula the size of a pinhead and purplish red in color **(Claviceps purpurea)** (Fig. 82). These capitula constitute "receptacles," in the surface of which are embedded closely packed, flask-shaped perithecia (Fig. 83 and 84), the mouths of which project slightly beyond the surface. The perithecia contain numerous cylindrical asci which each contain eight single-celled spores (sp). If these spores lodge on blooming grasses they develop into sphacelia; the latter, in turn, develop into ergot.

For the control of ergot it is recommended that the "spurs" be picked off while the grain is still in the heads. Since ergot has a pharmaceutical value, the collected product may be sold. Care should be taken that seed grain is free from infection. Grasses growing along fences and the borders of fields should be mowed off before the grain comes in bloom, or removed entirely.

Hygienic importance.—Ergot is toxic for man as well as for animals. In former times before the advent of cleaning machines, it was practically unavoidable that ergot was ground up with the grain and thus found its way into flour and bread, and was consumed by human beings and animals. Serious outbreaks of disease (ergotism) with numerous fatalities were the result. Serious cases of poisoning are known to have occurred in the 16th and 17th and more particularly in the 18th and 19th centuries. Rye, the cause of the disease, contained 3 to 5 per cent ergot. At the beginning of the 19th century Holland, Spain, Austria, Greece and England had become free from ergotism. In Germany the last serious outbreaks of ergotism in man occurred in Chemnitz (1867) and Frankenberg (1879). In the Balkans the disease still occurs occasionally. In Germany the disease appears among animals even to this day, as a result of dishonest practices (adulteration, etc.) in the handling of feeds.

According to Kobert, ergot contains three toxins: (1) An alkaloid, cornutin or secacornin, which causes contractions of the uterus (abortion), contraction of the blood vessels, general muscular spasms and stiffness; in large doses, paralysis of the respiratory center. (2) A glucosid, ergotinic acid (sclerotinic acid), which is effective

only when injected subcutaneously or intravenously. It decreases the excitability of the central nervous system. (3) Resinous sphacelinic acid, which produces gangrene as a result of hyaline degeneration and thrombosis of the peripheral arteries. According to Jacoby, sphacelinic acid is not a distinct compound but consists of resinous sphacelotoxin, which effects the contraction of the blood vessels; a nonpoisonous alkaloid, secalin, and ergochrycin. Sphacelotoxin with secalin forms secalintoxin; with ergochrycin it forms chrysotoxin. In the course of poisoning with sphacelotoxin, thrombosis of the blood vessels of the extremities occurs, followed by gangrene (Gruenfeld). Ergot contains also a pigment, sclererythrin, upon which the spectroscopic determination of the presence of ergot is based (cf. Klimmer, The Scientific Feeding of Animals).

Ergotism has frequently been observed among domestic animals. Cattle and poultry seem to be most susceptible. The disease is characterized by: (1) Gastrointestinal inflammation (inflammation, vessicle formation, erosions and gangrene, particularly of the buccal, rectal and vaginal mucousæ; vomiting (pig), colic, diarrhea). (2) Necrosis of the skin and even of the underlying tissues on the legs (the claws, sometimes the entire carpus and metacarpus, the ears, tail, teats; in poultry the comb and wattles, toes, wings and tip of the tongue) preceded by lameness, dermatitis, etc. The necrotic areas of the skin become dry; demarcation and sloughing follows. (3) Uterus contractions (abortion, prolapsus of uterus and even of rectum). According to Albrecht, pregnant cattle, sheep, goats and dogs are very resistant to this action of ergot. (4) Nervous derangements (dullness, somnolency, anesthesia, symptoms of paralysis, mydriasis, blindness (cataract), spasms of the flexor mucles).

Ergotism has been observed in horses, cattle, swine, sheep and poultry. It is mostly brought about by feeding on meal containing the fungus, more rarely through the medium of hay, or directly from pastured stubble. The presence of the mycelium of ergot can be recognized by means of the microscope or demonstrated by chemical means (Klimmer, The Scientific Feeding of Animals, 3d ed.). Ergot content exceeding 0.2 per cent in flour is looked upon as dangerous.

II. Injurious Agents of Animal Nature

The number of animal parasites of cultivated plants is very extensive, but only a few of them concern us here, since it is exceptional that they affect the health of animals.

The well-known green, or yellowish green, black-punctated and yellow striped larvæ (worms) on cabbages and turnips (cabbage worms) (larvæ of **Pieris brassica** L., **P. rapæ** L. and **P. napi** L.) often appear in enormous numbers. They multiply rapidly, producing two or three generations in one year. They feed on the leaves

of the different varieties of cabbage, rape, turnip, radish, etc., devouring all but the largest ribs. When ingested in large numbers, with green forage, they may produce serious and even fatal disease in

Fig. 85. Plant lice (x 18). *a*, *Aphis papaveris*, wingless; *b*, *Aphis loti*, wingless. (Kirchner and Boltshauser.)

Fig. 86. Plant lice of field bean (natural size). L, plant lice (*Aphis papaveris*). (Kirchner and Boltshauser.)

Fig. 87. Spanish fly (*Lytta vesicatoria L*).

Fig. 88. Garden or field slug, or common land snail.

animals. The usual symptoms are gastroenteritis, stomatitis, hematuria and weakness in the lumbar region in cattle and ducks. Postmortem findings in ducks are often of a negative nature. Koepke reports similar affectations in a horse and a cow caused by **Aporia cratægi L. (a white butterfly).**

The cause of the pathogenic action of larvæ (caterpillars, so-called worms, etc.) has as yet not been explained. It is supposed that the injury results from the presence of some unknown chemical substances or perhaps the mechanical effects of the hairs and bristles on these insects. The larvæ of the processionary moth of Europe

(**Cnethocampa**, especially **C. processionea** of the oak and coniferæ) have very sharp bristles (stinging hairs).

There are many ways in which these larvæ, or sometimes only the hairs or bristles, may contaminate feeding stuffs and when ingested cause inflammations of the skin or of the mucous membranes of the eyes and mouth.

Among other insects the Spanish fly, **Lytta vesicatoria,** should be mentioned (Fig. 87). During the month of June this emerald green beetle (1 to 2 cm. long) infests various deciduous trees, especially young ash, which it completely denudes. As is well known, it is the source of the blistering principle, canthardidin. This beetle is very common in southern Europe, but many other species of similar character exist in other parts of the world. It is rarely an object of food contamination. Should this be the case, however, and if ingested, serious poisoning results (abortion, hematuria, stomatitis and gastroenteritis).

American reports show that chicks, after feeding on a small beetle (**Macrodactylus subspinalis**) found on daisies and grasses, became sick and died. These beetles seem to contain a cardiac poison.

Plant lice (Aphidii, Family Hemiptera, Figs. 85, 86) sometimes literally cover plants. If ingested in quantity they may cause an inflammation of the skin (vesicular exanthema), especially of the white areas. These dermatites, which may be attended with partial necrosis, have been observed in horses and cattle on the feet, extending to the hock and carpus, on the udder and on the lips. Plant lice may also be the cause of vesicular and necrotic stomatitis and of conjunctivitis. Enteritis has been observed in swine. Infested forage plants, dried and converted into hay, are harmless.

In past years the common land snail or slug, **Limax agrestis** (Fig. 88) (about 2 cm. long, without shell, brownish gray with black feelers), has been observed as the cause of disease. They feed upon various forage plants (Leguminosæ, cabbage, etc.) during the night or in damp cloudy weather, and may thus be harvested with the green forage. Stomatitis and pharyngitis in cattle have been observed to follow their ingestion. The application of unslaked lime on the affected plants, either in the evening or early in the morning, is recommended for the destruction of the snails.

III. Injuries to Feed Due to Weather and Soil Conditions

Continued rains reduce the nutritive contents of plants. Heavy showers soil the plants with earth, destroy tender leaves, cause the lodging of grain, etc. Continued rains leach plants that have been cut and left in the field; such plants may lose from 25 to 40 per cent of their nutrient substances. Saprophytic bacteria and molds may spoil forage thus exposed. Roughage thus affected may be made more

palatable and digestible by the addition of salt. Where necessity demands that slightly spoiled (moldy) forage be fed, it should previously be cut up and steamed, or at least scalded. Cut grains when exposed to continued rains will sprout, which causes 20 per cent of the albuminous matter to be converted into worthless amid compounds.

Floods may cause forage to be contaminated with sand and mud. (See p. 162 in regard to lead deposits.) Sandy forage may cause the accumulation of sand in quantities ranging from 10 to 15 pounds in the digestive canal and lead to serious paresis, constipation, colic, buckling and volvulus of the intestine, disorders of nutrition, necrosis of the intestinal mucous membrane, and death. In horses the sand usually collects in the colon, especially in the pelvic flexure and lower layer; less frequently in the cecum. Habersang observed recovery in horses, following the administration of arecolin (discharge of sand). Barnstein relates a case in which a daily ration of 6 lbs. of barley feed with 2.6 per cent of sand caused the death of a cow. Muddy or silted forage, when dry, is very dusty and may produce inflammations of the conjunctiva, anterior respiratory tract and lungs, indigestion and gastroenteritis. The simplest remedy for the prevention of these unfavorable consequences consists in permitting flooded forage to be washed by succeeding rains, or in dusting the dry forage. Very frequently flooded or mud-covered plants will die, become a prey to saprophytes and, if fed in this condition, lead to serious consequences (gastroenteritis, nephritis, abortion, putrefaction intoxication).

In regard to flooding by rivers, contaminated with lead compounds, see page 162.

Many plants are killed by frost. When the weather moderates they may decompose, and if fed to animals may produce serious disease (inflammation of the stomach, intestine and kidneys, abortion and poisoning).

When it is impossible or impracticable to feed frozen potatoes and turnips fresh, before they decompose, they may be preserved by ensilaging. If feedstuffs are ingested in their frozen state they often cause gastric catarrh, bloating, colic and diarrhea, sometimes even abortion. In feedstuffs rich in starch, (potatoes), temperatures below 6° C. (42.8° F.) convert a large part of the starch into sugar. Potatoes thus altered are not injurious to health.

IV. Smelter Contaminations

On page 34 attention has already been directed to the presence of smelter fumes in certain restricted areas. These fumes condense on the surface of plants wet with fog, dew or rain and cause serious damage, especially to clover and other plants in their early (suc-

culent) stage of growth. Grasses are less affected. The affected parts become spotted, shrivel and die. Until 1870 smelter fumes caused much damage in the neighborhood of smelter works at Muldenhuetten, Freiberg, the upper and lower Hartz region, Westphalia and Upper Silesia[1], but during recent years this has been much reduced by the installation of special apparatus for the condensation of the fumes, the control of the dust and the building of higher smokestacks to increase the area over which the escaping fumes are disseminated.

Of the poisonous elements present in smelter fumes the most important are sulphurous acid, arsenic, lead and zinc.

Sulphurous acid, in contact with air, is oxidized and becomes sulphuric acid. It has a caustic, corrosive effect on plant life. In Germany arsenious acid is no longer of importance in this respect. The insoluble compounds of lead and zinc may be looked upon as harmless to plant life, while their soluble salts are injurious[2].

Hygienic importance.—When plants, injured by smelter fumes, retarded in their development, partly dead, composed for the greater part of indigestible fiber and consequently of low nutritive value, frequently even causing aversion, are fed to animals, especially cattle, the result is loss of appetite, disturbance of the digestive functions and nutrition (diarrhea, emaciation, etc.), and sometimes catarrhal conditions of the respiratory tract, or bone affections (halisteresis ossium). The latter are ascribed to the fact that the sulphuric acid decalcifies the soil. As a result the vegetation produced on such soil is deficient in lime salts and the animals subsisting on it suffer from the same trouble (brittleness and softness of the bones). Furthermore, the increased amount of sulphuric acid in the plants seems to affect the amount of phosphates and prevent the best utilization of the lime salts in the animal body. The bad effects on the bones may be counteracted to some extent by the administration of salts of lime and phosphoric acid, preferably as constituents of regular feedstuffs.

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[1]Fifty years ago, in the smelter regions of Freiberg, 10,000,000 pounds of sulphuric acid were annually dissipated into the air with the smelter fumes and only 1,820,000 pounds were saved. At that time there disappeared through the smoke stacks of five smelters in a single day:

330 lbs. of arsenious acid,
2,610 lbs. of sulphate of lead,
2,990 lbs. of sulphate of zinc,
270 lbs. of zinc oxid,
410 lbs. of sulphuric acid,
880 lbs. silicic acid,
2,650 lbs of oxid of iron and alumina.

By the employment of certain measures of conservation it was possible to reduce the loss of sulphuric acid about 66 per cent, but in spite of this the daily loss of sulphurous acid exceeded 10,000 pounds.

[2]Formad (in 25th Annual Report, Bureau of Animal Industry, U. S. Dept. Agri., 1908 [1910] reports an investigation of the effect of arsenic-laden smelter fumes and flue dust on livestock in the Deer Lodge Valley of Montana. The quantity of arsenic contained in the daily emanations was estimated at from 22 to 30 tons. This was distributed and precipitated over an area of several miles, with resultant damage to plant and animal life. Animals pasturing on the contaminated vegetation became unthrifty and suffered from digestive disturbances, death sometimes resulting. Characteric ulcers appeared in the nostrils. Chemical examinations revealed arsenic in all parts of the body.—J. R. M.

If the feedstuffs contain particles of arsenious acid the latter may cause excoriations or inflammations of the abomasum, less frequently of the paunch, and all other symptoms of chronic arsenic poisoning. If the arsenious acid is present on roughage, it may be inhaled in the form of dust and cause excoriations of the respiratory tract and inflammations. Catarrhs of this character are usually of a chronic nature, and, like similar conditions of the respiratory tract, favor infection with tubercle bacilli. Scattered areas of the protecting epithelium may become excoriated and thus the effectiveness of the ciliated epithelium reduced. As a matter of fact it has been observed that tuberculosis gained an unusual prevalence among the cattle in the region of Freiburg (Siedamgrotzky, Johne).

Poisoning with lead and other metals have not been observed in the Freiberg region. To what extent lead poisoning, observed in other smelter districts, may not be due to smelter fumes, is still an open question. Zimmermann relates a case of lead poisoning in thirty cows, in a herd of eighty, caused through the medium of beets. The beets had been washed at a distance of 1 kilometer from a lead smelter, near but not within the flood district of a certain stream. Samples of earth scraped from the beets contained 0.02 per cent of lead, while samples of earth taken from the beet field contained 0.43 per cent. The lead was present in the metallic form and not as sulphid or silicate. Freitag, however, states that the sulphuric acid of smelter fumes combines with the lead fumes to form insoluble, and therefore harmless, lead sulphate, which, having a high specific gravity, settles rapidly and consequently is found only in the immediate vicinity of smelters.

Instances of lead poisoning in the vicinity of smelters may often be traced to streams that are contaminated in the process of hydraulic mining and other manipulations of the ore. In times of flood such streams deposit not only lead, but occasionally also arsenic, zinc and copper, on fields and meadows in the flood area. These substances contaminate the forage, which, when consumed by animals, produces the poisonings in question. Finally, dust containing arsenic, lead, etc., may be carried by the wind from mounds of stored ore, and spread over fields. Lead poisoning resulting from the flooding of fields is most frequently observed on the banks of the river Innerste in Hildesheim as well as in the districts of Schleiden and Euskirchen of Rhenish Prussia. They occur in goats, dogs, poultry and, above all, in cattle.

The symptoms of these forms of lead poisoning consist of salivation, constipation, more rarely diarrhea, diminished appetite and secretion of milk, suppressed rumination, mental excitement and rabiform symptoms followed by exhaustion, stupor, paraplegia, anesthesia, coma, paralysis of tongue, hard pulse, reddening fol-

lowed by discoloration of the mucous membranes, labored and increased respiration and abortion. In horses paralysis of the muscles of the pharynx (roaring) and colic predominate. The lead is usually ingested with turnips or beets and their leaves, less frequently with hay or grass. The lead is not found in the tissues of the plants but adhering to their exterior, mixed with dirt or mud.

Preventive measures consist in the exposure of green forage to the cleansing action of rain, the "dusting" of dry fodder, the thorough cleansing of root crops, and, finally, regulation of streams to prevent flooding.

Modern improvements in smelter works, installation of settling basins, etc., have resulted in a diminution of lead poisoning in recent years.

Weynen observed cases of zinc poisoning among swine in the neighborhood of zinc smelters. The symptoms were loss of appetite, diarrhea, groaning, emaciation, exhaustion. Roebert reported acute arsenic poisoning in sheep that were pasturing in a clover field near a smelter.

Finally, poisoning has followed the ingestion of leaves (grape) and grain (wheat) which had been sprayed with sulphate of copper for the control of fungus diseases (page 133), and the feeding of beets that were grown on a field that had received factory drainage containing copper salts (cf. also the following).

C. The Spoiling of Stored Feeding Stuffs

Stored feeding stuffs may become spoiled by the admixture of chemical poisons as well as through the vital activity of certain animal and vegetable parasites and saprophytes. Conforming to the plan followed in the preceding pages, only those harmful agencies will be considered as in turn may exert harmful effects upon domestic animals.

I. Chemical Poisons

When not properly stored or prepared, feeding stuffs may easily become contaminated with admixtures of dangerous chemicals (copper, lead, zinc) and cause poisoning of animals.

Copper poisoning is most frequently observed when sour or fermenting feeding stuffs containing starch and sugar (such as slops, etc.) are kept in copper vessels with the contents exposed to the air, and then fed to animals. The symptoms are those of acute poisoning—gastro-enteritis (vomiting, loss of appetite, colic constipation or diarrhea), muscular paralysis, weakness, anesthesia, labored breathing and cardiac paralysis. (Cf. Copper Poisoning, above.)

The causes of **lead poisoning** are usually found in feeding stuffs that have been kept in vessels painted with red lead, more rarely

defectively glazed or enameled ware. Pawlat reports an instance of lead poisoning caused by a lot of lead shot administered in a gruel. Lead poisoning has also been known to result from the feeding of cocoanut cake and meal contaminated with lead ore. (For symptoms see p. 162.)

Hahn reports instances of **zinc poisoning.** Cattle had been fed with masses of "dough" scraped from the zinc bearings of a millstone and made into a slop. Following this, symptoms of zinc poisoning were observed (p. 163). The presence of zinc oxid was demonstrated.

To be familiar with these forms of poisoning is all that is necessary to avoid them.

II. Injurious Agents of Animal Nature

Among the noxious animal agents the following are important: **Tenebrio molitor** L. (Fig. 89), the larva of which is known as the meal worm; **Calandra granaria,** grain weevil or grain borer, its black

Fig. 89. Meal weevil and meal worm, *Tenebrio molitor L.* (Taschenberg.)

Fig. 90. Grain weevil or borer, *Calandra granaria L.*

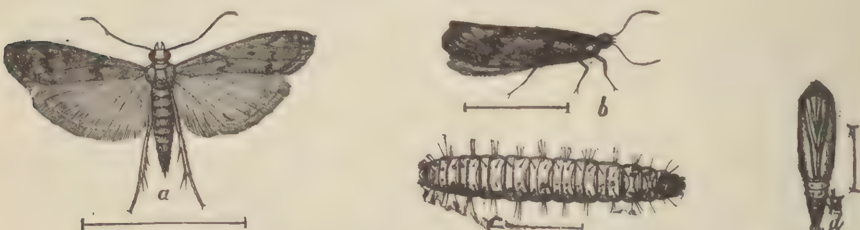


Fig. 91. Meal moth, *Pyralis farinalis.* (*a*, flying; *b*, at rest, *c*, larva, *d*, pupa.)

larva being known as the black grain worm; the larva of the meal moth, **Pyralis farinalis** L. and **Ephestia kuehniella** Z. (Fig. 91); the grain moth, **Tinea granella** L. (Fig. 92), the larva of which is known as the white grain worm; the sugar slicker, **Lepisma saccharina** (Fig. 93); the wheat eel, **Tylenchus scandens** Schn. (Fig. 94), and several species of mites, **Acarus farinæ** (common meal mite), **Acarus plumiger** (plumed meal mite) **Tyroglyphus farinæ** C. L. Koch, etc. (Figs. 96-98).

The worst enemies of stored grain are the white and the black grain worm (larvæ of **Tinea granella** L. and **Calandra granaria** L.). They completely destroy the grain, leaving the empty shell. The black grain worm (Fig. 91) is thick and short, about 3 mm. long, naked, whitish, with brown head. This is transformed into a snout beetle, or curculio, nearly 4 mm. in length and of a uniformly brown color, punctated. Preventive measures recommended consist of frequent turning and ventilation or airing of the grain. Before storing, all cracks in bins should be carefully sealed and walls and ceiling whitewashed. To detect the presence of the beetles, a sample of the grain is placed on a warm surface (pan or board), when they appear on the surface.

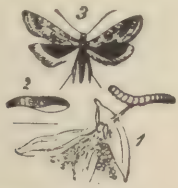


Fig. 92. Grain moth, *Tinia granella L.* 1, White grain worm with nest; 2, pupa; 3, grain moth (slightly enlarged). (Taschenberg.)

Fig. 93. *Lepisma saccharina*, slicker.

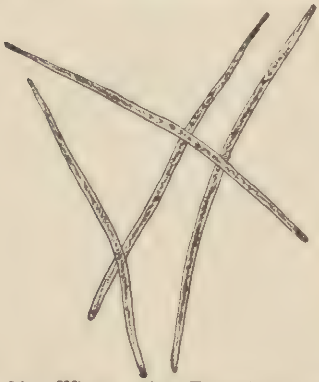


Fig. 94. Wheat eels, *Tylenchus scandens* Schn. (X 15.)

Fig. 95. *Anobium paniceum*, death watch.

Hygienic importance.—Germain relates that horses, after being fed on barley that had been almost completely destroyed by the weevil and been converted into a fine dusty mass (and only a careless attempt to remove the dust), became affected with a "lung disease" of typhoid character. After the remainder of the barley was washed, and fed "wet" the disease disappeared. Judging from the details of the report, it would seem that the inspiration of the dusty mass caused pneumonia (pneumoconiosis) and that the grain weevil was only indirectly responsible for the trouble.

Anobium paniceum (death watch).—The larva of this beetle (Fig. 96) frequently occurs in spoiled, lumpy, rice feed meals originating in foreign rice mills.

The white grain worm (Fig. 93) is about 8 mm. in length, slender in form and white in color. It has a habit of clumping grain by spin-

ning a web about a number of seeds and then feeding upon them. Preventive measures are the same as recommended for the black grain worm. No pathogenic qualities have been attributed to this larva.

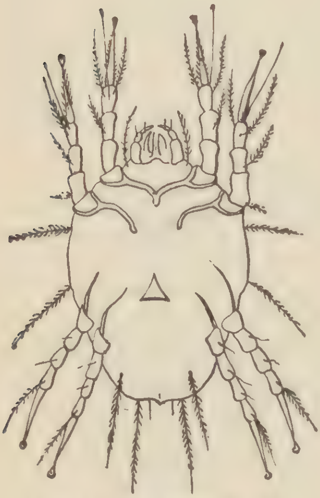


Fig. 96. Hay mite. (X 75.)

Fig. 97. Plumed mite.

Fig. 98. Meal mite, *Acarus farinae*. *a, a,* Eggs; *b, b,* young mites; *c, d,* mature mites.

The hay mite (Fig. 96) is almost microscopic in size. In the immature stages it is a whitish, soft shelled creature (acarina) with an oval body covered with plumed bristles, has a beak-like head and four pairs of legs, brownish and covered with bristles. The distal ends or joints of the legs (digiti) are cone shaped and each terminates in a sucker and a claw.

This mite is present in almost all hay. In old hay that has been stored in a damp place, or has become moldy, it may be present in very large numbers. It causes the hay to spoil and be transformed into a dusty mass. It is hardly probable that the hay mite has pathogenic properties or that it is injurious to the health of animals in any way, as was formerly frequently supposed. The same may be said of the meal mite (Fig. 98) which is often present in old, spoiled and damp meal or flour, bran, cracked grain and grits, occurring principally in the "lumps."

To detect their presence a tablespoonful of suspected meal is placed on a sheet of paper and spread out in a thin layer by covering and manipulating with a plate of glass. If mites are present they will produce little mounds in their endeavor to reach the air. The number of the mounds formed is an indication of the extent of their presence. Another method is to fill a glass receptacle, of about one-half pound or one pound capacity, with the suspected meal or flour, being careful to shake it down firmly and leveling off the top surface. After twenty-four hours the tunnels that the mites have made will be visible behind the glass. If the mites are numerous the surface appears minutely furrowed.

Meals and other feeding stuffs infested with mites are of inferior quality, palatability and wholesomeness. Since, according to Maurizio, the mites do not multiply very fast unless the moisture content is at or above 15 or 16 per cent (which is the requirement for molds), their presence in great numbers is suspicious.

III. Injurious Vegetable Agencies

Among vegetable parasitic life, mold fungi and bacteria are the chief agents that are active in spoiling of feeding stuffs. According to Koenig, the mold fungi **(Penicillium, Aspergillus, Mucor** and **Oidium)** predominate when the moisture content ranges from 14 to 30 per cent. When the moisture content exceeds 30 per cent the bacteria gain the upper hand. Mold fungi will not thrive in substances with a moisture percentage below 14. The harvesting and storing of feeding stuffs in a thoroughly dry condition is therefore the best preventive against molding. Mold fungi which also thrive on slightly acid media live on fat and carbohydrates while albuminous substances are only slightly or not at all effected by them.

The formation by them of deleterious substances could not be demonstrated by Koenig, Zippel, Barthelat, Lode and others, while Otto discovered an active spasmotoxin in two Italian strains of **Aspergillus fumigatus** (negative in five German strains), active also per os in rabbits and guinea-pigs. The Italian strains were active in summer only, not in winter. The Germain strains of **Penicillium** showed slight toxicity (sopor), only the Italian strains produced excitability. The toxins are not present in the growing media. Leber determined a poison (phlogosin) in cultures (the spores) of **Aspergillus fumigatus** and **Penicillium glaucum.** Gosio found a phenol compound (characteristics not clearly determined) and Pietro a poison in the spores of **P. toxicum** (presumably a glucosid) that produced spasticparetic symptoms with increased reflexes and tonicity of muscles (affection of the spinal cord). Furthermore, Ceni and Besta described a stimulating spasmotoxin obtained from **Aspergillus fumigatus** and **A. flavescens** as well as from certain species of **Penicillium,** and a toxin producing paralysis in **Aspergillus ochraceus** and **A. niger** and in several species of **Penicillium.** The degree of toxicity is said to vary according to the season of the year. According to Iwanow **Aspergillus niger** forms a certain amount of thyrosin on the seeds of the yellow lupine, in addition to a large amount of leucin and ammonium oxalate.

Mold fungi produce an unpleasant musty odor in feeding stuffs and a strong or bitter, nauseous taste.

The action of bacteria is manifold. Some of them are the cause of rapid destruction of albuminous substances; others, like those of the lactic-acid group, live principally on carbohydrates and produce acids, thus inhibiting the development of the albumin-destroying bacteria. Certain saprophytic bacteria are capable of producing very violent toxins, as, for example, the anaerobic **Bacillus botulinus,** which develops in meat products, canned goods, etc., and has frequently been the cause of serious disease (botulism). Species of **Proteus,** etc., belong to the same class. While toxic bacteria have not been found in or on vegetable feeding stuffs, there are many cases of poisoning where their presence may be taken for granted.

1. Mold Fungi

The most important mold fungi found on feeding stuffs are the following:

1. **Mucorales** (Fig. 99). These are characterized by endogenous spore formation in terminal sporangia, associated with zygospore formation following copulation. Under the microscope they are easily recognized by the terminal globular sporangia. There are numerous species.

2. **Aspergillales** (Fig. 100). These are characterized by sexual reproduction, ectogenic spore formation at the end of numerous sterigmata situated on a club-shaped swelling (columella) of the

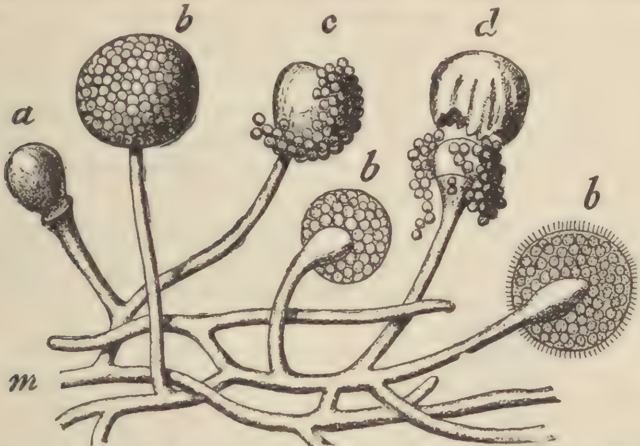


Fig. 99. *Mucor*. *a*, Columella denuded of sporangium and spores; *b*, complete sporangium; *c*, sporangium and part of spores removed; *d*, sporangium elevated, sports dropping off; *m*, Mycelium. (X 300.)

Fig. 100. *Aspergillus*. *a*, Mycelium; *b*, columella with sterigmata; *c*, lateral view of same with spores; *d*, viewed from above. (x 100.)

fruiting hyphæ (basidia). Appears under the microscope as an "open" irregular capitulum. **Aspergillus glaucus, A. fumigatus, A. flavus, A. niger, A. subfuscus,** etc.

3. **Penicillium glaucum,** (common blue mold) (Fig. 101). Characterized by sexual reproduction, ectogenic spore formation on

secondary sterigmata, the latter in groups of three on two primary sterigmata of the fruit-bearing hyphæ (basidia).

4. **Oidium lactis** (milk mold, Fig. 102). Spores arranged in chains at the ends of simple or branched conidia-bearing hyphæ (basidia).

While most of the mold fungi under consideration are simple saprophytes, certain forms may become parasitic in the bodies of animals and give rise to serious and fatal disease. **Mucor corymbifer, M. rhizopodiformis, M. pusillus** and **M. racemosus,** as well as **Aspergillus fumigatus, A. flavus, A. niger, A. nidulans** and **A. subfuscus,** are looked upon as pathogenic.

When the spores of these fungi are injected into the circulation of guinea-pigs, the latter will succumb in the course of two or three days. Upon microscopic examination the blood vessels are found to be crowded with a mass of mycelium. Fructification, however, does not occur.

Fig. 101. *Penicillium.* (x 200.)

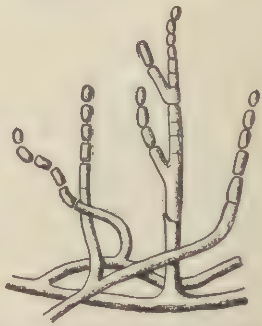


Fig. 102. *Oiedium lactis.* (X 200.)

Under natural conditions the effects of pathogenic mold fungi and their spores are always of a local character, inflammatory foci at their port of entrance, cornea, external auditory meatus, guttural pouches and lung. To produce these conditions or infections, it is necessary that large quantities of the spores of mold fungi be introduced, as may occur in the feeding of roughage affected with the pathogenic fungi in question. The spores are scattered with the dust, lodge in the eyes, are inhaled, or enter the external auditory meatus. Mycoses of the external auditory meatus and of the cornea have been observed in man. Among animals, horses, cattle, lambs, rabbits,

poultry, pigeons, geese, ducks, pet birds, etc., mycotic lung affections (pneumonia asperigillina) have occurred, even in the form of epizootics. Weak, pampered individuals are the most frequent victims. In mammalia pneumomycosis aspergillina usually appears in the form of a nodular, purulent or necrotic pneumonia. Roeckl described diffuse pneumonias in the ox; macroscopically they resemble contagious pleuropneumonia. Occasionally symptoms of bronchitis are present. In poultry, which suffers most from this form of mycotic inflammation, not only the lungs and bronchi but the air sacs of the nasal cavities become affected. In the lungs the nodular form predominates, while diphtherioid coatings are formed on the mucous membranes.

The other purely saprophytic mold fungi, whose maximum growing temperature is below 37° C. (98.6° F.), and which therefore can not grow in the animal body, are by no means harmless under all circumstances. They may be the cause of serious disease. The injurious principle of the purely saprophytic mold fungi must be looked for among the chemical poisons. It is not as yet understood under what conditions these poisons are formed. It is known, however, that in most cases the poisons in question are not formed and that moldy feeding stuffs have frequently been ingested without causing the least harm. When these poisons have been formed, on the other hand, they may seriously affect the health of animals.

Poisoning by mold fungi has been observed in horses, cattle, sheep, swine (especially young pregnant animals), and in poultry. Sheep seem to be more susceptible than cattle. The symptoms of poisoning by mold fungi are gastroenteritis (anorexia, colic, tympanitis, constipation, diarrhea—even bloody; in horses icterus also), or peculiar effects on the nervous system and even cerebritis (vertigo, blind stagger symptoms, anesthesia, apathy, sometimes symptoms of excitement). Additional symptoms are paraplegia (hind legs and bladder), paralysis of the tongue and pharynx (difficult deglutition, slobbering), paralysis of the ears, and general paralysis, or irritation of the kidneys and bladder (diabetes). In addition to the foregoing there may be excessive sweating, urticaria, very weak, accelerated pulse, rapid emaciation, not infrequently fatal termination within 12 to 24 hours. If recovery sets in there may be blindness, lumbago, etc., as sequelæ. Postmortem examination reveals inflammatory conditions of the stomach and intestines with punctiform hemorrhages, hydrocephalus, and edematous infiltration and hyperemia of the brain and spinal cord; sometimes peritonitis, nephritis and cystitis, and acute yellow atrophy of the liver. All of the anatomical changes enumerated may occasionally be absent.

In the **treatment** of mycoses the most important thing is to discontinue the feeding of moldy forage, etc. There should be thorough

evacuation of the gastrointestinal contents, followed by symptomatic treatment.

Mycoses have been observed following the ingestion of moldy bread, oats (musty oats), straw (especially baled straw, chopped straw and hay), hay, clover hay, meal, lupines, linseed cake, rape seed cake and other oil cakes, turnips and beets, chopped beets and turnips, malt sprouts, malt, fruit, squashes and pumpkins, etc.

Prevention.—Any moldy feed may possibly be the cause of serious or fatal disease. Whenever possible the feeding of such material should be avoided. If for economic or other reasons one is obliged to make use of material of this character, it would be advisable first to make experimental feedings on less valuable animals. Badly molded portions would best be destroyed in all cases. The danger may be lessened or entirely removed by previous drying, airing, sunning, threshing (roughage), shaking or screening (grains), as well as by cooking, steaming, etc. Scalding is less effective. The addition of salt to such feedstuffs is highly recommended.

The musty odor of grain may sometimes be removed by mixing with powdered wood charcoal. After two or three weeks the charcoal may be removed by running through a cleaning machine.

Most important of all is the prevention of moldiness. This is successfully accomplished by dry harvesting, dry storage with good ventilation (frequent turning of the grain in bins), protection from rain, snow, etc.; in emergencies, kiln drying, or drying in ovens or in special drying apparatus. The cautious use of unslaked lime, in wire or metal containers, set in bins or suitable inclosures, with the moldy feed, may be effective.

Fresh slops produced from moldy potatoes and meals seem to be harmless.

2. Bacteria

Among the bacteria, besides those of blackleg and anthrax, **Actinomyces,** Streptococci of enzoötic paraplegia (Zwick), there are probably others, as yet undetermined, that confer health-injuring qualities on feeding stuffs. Just as meat intoxications are due to specific bacteria, it is probable that similar causes underlie feed and forage poisonings. No doubt the agents concerned in the latter are primarily toxic species of bacteria (analagous to **Bacillus botulinus)** as well as infectious species (analagous to **B. paratyphosus).**

A number of substances that appear as preliminary and intermediate products in the decomposition of meat are known; thus, neuridin, neurin, muscarin, ethylendiamin, triethylamin, diethylamin, cholin, cadaverin, putrescin, saprin, sepsin, etc. The question of the nature and character of the toxins that appear in the processes of vegetable decompositions remains as yet to be solved. Cornevin

observed that water-soluble substances occur which produce intoxication when injected subcutaneously.

The symptoms resemble those of meat poisoning. On the one hand there are symptoms of gastroenteroses (mycotic gastroenteritis); on the other hand, various symptoms of excitement and paralysis as well as polyuria (horses). Intoxications of this character have been observed in horses, cattle, swine and sheep, after ingestion of rotten potatoes, beet leaves, tops and heads, as well as rotten or decomposed pulp and pressed pulp, brewer's grains, distiller's wash, decomposed rice flour, peanut cake, cottonseed cake, hay, fruit, scalded feed kept on hand for several days, etc. In herring and pickle brine poisoning, intoxication with sodium chlorid and saltpeter are occasionally supplemented with "ptomaine" poisoning, to which the nervous symptoms (mental excitement, spasms, pharyngeal paralysis, dysphagia), forced movements (traveling in a circle), rolling of eyes, etc., are ascribed.

Herring brine poisoning is common (in Germany) in swine, less so in poultry and other animals.

Identical symptoms have been observed following ingestion of sauer kraut brine or "pickle," spoiled animal foodstuffs, etc. Preventive measures for these so-called bacterial poisonings are the same as those recommended for mold poisoning.

Owing to our imperfect knowledge of the nature and qualities of the organisms concerned, the examination of feeding stuffs for mold fungi and decomposition bacteria is restricted to the application of comparatively crude and inexact methods.

A few grams of the feeding stuff to be examined are reduced to fine particles (by grinding or otherwise) observing aseptic precautions, and placed in a sterilized Erlenmeyer flask and thoroughly moistened with sterilized water, then kept at a temperature of 25° C. (77° F.) for 24 hours. If the feed was moldly, the sample thus prepared frequently becomes coated with a white layer of mold by this time. In the course of three or four days the same thing will happen with the best feeding stuffs. After the appearance of the "moldy coat" the examination is completed with our sense of smell. An odor of **slight** fermentation points to the absence of a previous "spoiled condition."

Section V

The Care and Management of Animals

Animals should be fed in a practical way (see Klimmer, Science and Study of Feeding, 3d ed.) and exercised sufficiently in the open (see p. 221 and under "Pasture and Exercising Lots"). The body must be cared for systematically, and finally the use, breeding, and rearing must to a certain degree be kept within the bounds of hygiene.

The care of the animals should be intrusted only to conscientious, quiet and observing persons. The number of animals that one person can care for depends upon the kind of animal, stable arrangement, preparation of the feed, use of the animals, etc. On the average a man can look after 15 to 18 head of cattle, or 34 to 36 head of young cattle, and a woman 10 to 12 or 16 to 24 respectively.

A. The Care of the Body

I. Care of the Skin

A very important part of the care of the body is the care of the skin. A systematic care of the skin is usually exercised only with horses; on the other hand, it is very often found lacking in the case of cattle and hogs. Proper care of the skin is not only advocated for the sake of cleanliness and in the interest of the use of the animal, but mainly because it is hygienically necessary. The skin, which is a vital organ and regulates the body temperature, can perform its function completely only when it receives proper care. This is especially true of stable animals which are deprived of the various atmospheric influences that cleanse and excite skin activity; but even in the case of pasture or range animals the care of the skin can not be entirely neglected, as is more fully explained in the section on "Pasturage."

The skin becomes soiled from the sweat with its organic compounds and salts, from the epithelial cells (scales) that rub off, from the products of the sebaceous glands and from the dust. The resulting dirty, greasy coating is conducive to the proliferation of bacteria, decomposition, reduction of the normal sensitiveness of the skin, and at times also to greater irritation of certain parts of the skin, to various skin diseases, to self-infection due to injury, and even to the entrance of pathogenic microörganisms. If the care of the skin is neglected vermin and the causative agents of skin diseases (mange mites, etc.) easily multiply.

The *lice* of our domestic mammals are classified as follows:

A. Subdivision: Mallophaga. *Skin eaters,* with biting oral apparatus and broad head (Fig. 103). To this group belongs the genus *Trichodectes,* which often occur in great numbers on all domestic animals excepting the hog. The favorite sites are the base of the horns, neck and root of the mane and tail. Injury is slight.

B. Subdivision: Siphunculata, with *stinging* oral apparatus and long, pointed head (Fig. 104). To this group belongs the family Pediculidæ, lice, with the genus *Hæmatopinus.* These occur in great numbers on all domestic animals excepting the sheep and the cat. They are usually found on animals that are poorly cared for. Their favorite sites are the neck, the back and the base of the tail. Their stings cause violent itching and with increased numbers the development of eczema and scab.

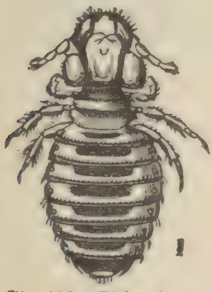


Fig. 103. Biting louse (*Trichodectes*).

Fig. 104. Sucking louse (*Hematopinus*).

Fig. 105. Hair mite (*Demodex*).

The lice and hair eaters can easily be removed with a piece of blue (mercurial) salve about the size of a pea which is rubbed with oil into a thin paste. The salve is then applied to the most infested parts; the animals are then rubbed so that the salve spreads over the entire body. In case of cattle the mercurial salve should be avoided; it is best to use petroleum for them. The treatment should be repeated after four days.

Mange (scab) is caused by mange (scab) mites. Among our domestic mammals four genera of these mites must be considered.

1. *Demodex folliculorum,* hair-follicle mite, which can easily be recognized by its elongated, wormlike posterior part, square head and four pairs of stumpy legs with claws (Fig. 105). *D. canis* (Leydig) causes the worst mange of the dog and the most difficult to treat—the acarus mange. Likewise *D. cati* (Railliet) causes a severe form of mange of cats and *D. phylloides* (Csokar) of hogs. *D. copræ* (Railliet), *D. bovis* (Stiles) and *D. equi* (Railliet) should also be mentioned.

2. *Sarcoptes,* burrowing mite. Body is tortoise-shaped, head square, hind legs joined to body on the abdominal side covered by the posterior part of the body. Suction discs are hemispherical with

rather long, jointless stems; back has spines, scales and bristles (Fig. 106). *Sarcoptes equi* (Gerlach) produces sarceptic mange in solipeds (Fig. 107).

Fig. 106. *Sarcoptes,* burrowing mite.

Fig. 107. Sarcoptic mange in horse.

S. ovis (Mégnin) produces mange in sheep on the portions of the head not covered with wool. *S. canis* (Gerlach) occurs on dogs and *S. capræ* (Fuerstenberg) on goats, *S. suis* (Gerlach) on hogs, *Notœdres cati* (Hering) on cats, *N. cuniculi* (Gerlach) on rabbits, where they also cause mange.

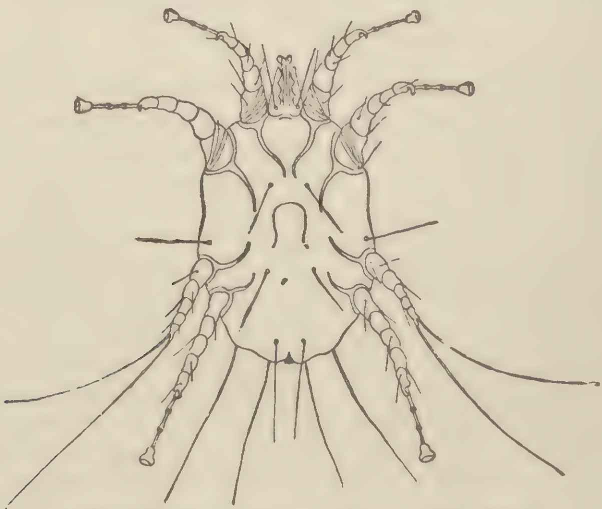


Fig. 108. *Psoroptes, Dermatocoptes;* sucking mite.

3. *Psoroptes* (*Dermatocoptes*), sucking mites, have a biting or stinging oral apparatus, i. e., a long pointed head, suction discs that are lily or trumpet shaped with trijointed stems (Fig. 108).

Psoroptes equi (Hering) causes psoroptic mange among solipeds. *P. ovis* or *P. communis ovis* (Hering) produces the common scab or scabies of sheep. *P. bovis* (Gerlach) (or *P. communis bovis*) appears among cattle, *P. capræ* among goats and *P. cuniculi* (Delafond) among rabbits (ear mange).

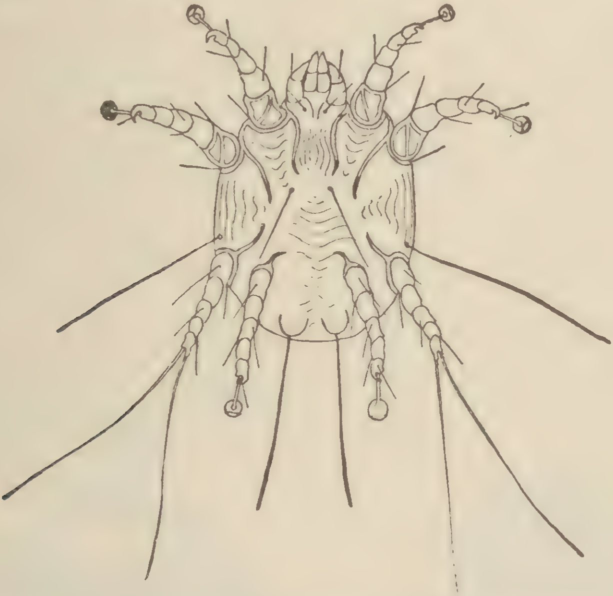


Fig. 109. *Chorioptes, Dermatophagus,* scale-eating mite.

4. *Chorioptes* (*Dermatophagus*), eating mites have an eating oral apparatus, i. e., head broader than long, suction discs bell-shaped with short nonjointed stems (Fig. 109). *Chorioptes equi* (Gerlach) causes foot mange among horses, *C. bovis* (Gerlach) rump mange among cattle,

Fig. 110. Curry comb and curry brush.

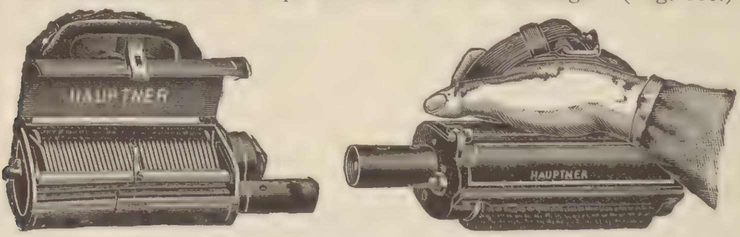
C. ovis (Railliet) pastern mange among sheep, *C. cuniculi* (Zurn) ear mange among rabbits, *C. capræ* (Gervais and Beneden) foot mange among goats. *Otodectes cyonotis* occurs in the auditory passages of the dog and the cat ear mange). Chorioptic and Otodectic mange is generally mild.

For the treatment of the various forms of mange sulphur dioxid gas has generally been successful; only in case of acarus mange of dogs does it seem to fail.

As has already been mentioned, regular care of the skin is essential. Its purpose is two-fold: (a) Cleansing the skin of dirt, vermin and pathogenic bacteria; (b) stimulating activity of the skin. The means of skin treatment are: 1. *Cleaning.* Since creating a certain amount of dust can not be avoided when currying animals, this should be done out of doors if possible. When shedding hair, animals should be protected from the wind and intense heat of the sun. It should not be done while feeding, because many animals become restless when being cleaned and are provoked into too rapid eating or wasting of feed. For cleaning the skin the curry brush serves best. The brush should be stroked out on the curry comb (Fig. 110) and freed of the accumulated dirt. The curry comb should be used only to loosen matted hair.

The curry brush is a brush with short, stiff horse hairs and a wooden back. To facilitate a better hold on the brush a strap is fastened across the back under which the hand with the exception of the thumb is thrust. (Fig. 110.)

The curry comb is made of a square piece of sheet iron with a handle and with 6 to 8 narrow notched strips of sheet iron set on edge. (Fig. 110.)



Closed. Open.

Fig. 111 Hauptner's grooming machine.

In America cleaning machines based on the principle of vacuum cleaning apparatus have been constructed, but they have not proved satisfactory, although Lavolard praises them highly. Three men are supposed to clean a horse in five minutes with the Goodwin machine. Hauptner in Berlin has put on the market a cleaning machine that is constructed according to the principle of rotating brush rollers (Fig. 111). This machine can be attached to the Hauptner shearing (clipping) machine (Fig. 114).

Horses should always be curried regularly each morning, and if they have become very dirty or wet they should be cleaned again after work in the evening. The cleaning should be done systematically, so that no parts of the body will be overlooked. Always begin with the head. The brush should be used with long strokes and generally in the direction in which the hair grows. It should then be cleaned out by brushing it over the metal teeth of the curry comb, which should be knocked out from time to time so that the air in the

stable will be polluted as little as possible. To determine whether or not the cleaning has been thoroughly done, rub the fingers along the head, neck, back, belly and legs in the opposite direction to that in which the hair grows. No gray streaks should result from this. Also part the mane and tail hairs with both hands and examine down to the skin.

If it is necessary to use the curry comb on the animal, care should be taken not to injure the skin of the horse with the metal teeth of the comb. Very thin-skinned, pure-bred horses are sometimes cleaned only with a mitten made of coarsely woven horse-hair (Arabian brush). Special attention should be given to the lower part of the legs (below the knee and hock), which are especially apt to become very dirty (p. 185). The hair of the mane, forelock and tail should also be brushed thoroughly. Careful attendants use a special comb for the mane. In combing one should be careful not to pull out matted or tangled hair. The body apertures should be wiped out with soft cloths or sponges which should frequently be thoroughly cleansed and boiled once a week. It is taken for granted

Fig. 112. Sweat scraping iron.

that the same sponge will not be used for eyes, nose, mouth, rectum and genital orfices. In order to prevent transmitting infectious diseases (influenza, glanders, strangles, etc.) special cleaning utensils, cloths and sponges should be used for each animal.

After cleaning, the coat should be brushed down once more with a roll of hay, tow, burlap, or some such material, which is given a flat surface by beating it against a wall, and which is grasped in both hands and drawn back and forth. Before harnessing or saddling the horse all the hair on the body should be rubbed smooth with a woolen cloth.

The winter hair can be most easily removed by stroking with the moistened hand; however, the removal of the hair should not be hastened too much.

Horses that are restless and that bite while being curried should be tied up short or muzzled. Gentle handling is far better than rough

treatment in their case. To tie horses by means of a rope passed through the mouth is very objectionable. The rope is apt to draw tight and may cause injury, especially if the rope is small.

After returning and being unharnessed the horses should be rubbed off with a straw whisk and the worst dirt should be cleaned off of the legs and belly.

Too frequent and too severe cleaning, which is often done with fancy horses, is not to be recommended, as the horses become too susceptible to colds.

Horses that are very much overheated and sweating profusely should be led about until the hair has dried and the pulse as well as the breathing subsided to normal. This is usually accomplished in 10 to 15 minutes. If, however, one is forced to stable overheated animals, they should be scraped with the sweatknife (an instrument resembling a knife but made of wood, rubber or metal with a dull blade) or scraper (Fig. 112; sometimes the edge is provided with a rubber plate); or if this is not at hand the sweat should be rubbed off with a whisk of straw, after which the horses should either be blanketed or rubbed dry with whisks of straw. Rubbing dry with the straw whisks is customary and usually harmless, but it should be borne in mind that the sweat mixed with dust is rubbed into the skin and may thus produce the heat rashes which are dreaded during the summer.

This does not mean, however, that the horses should be put into the stalls wet and left to themselves. Rubbing dry should serve only as a makeshift. The same treatment should be followed with horses that have been drenched with rain or snow. The legs also should be rubbed dry. It is of course understood that horses drenched or overheated should be protected from cold draughts.

After unharnessing fine horses it is very beneficial to rub into the skin over the entire body with a sweat knife a soap solution prepared from one-half pound soap or tar soap and one litre (quart) of water, and then to rinse at once with warm water. In this way all dirt is also immediately removed. At the finish the horse should receive a cold douche with an ordinary sprinkling can. Not until after this should the horse be quickly and thoroughly rubbed dry with the straw whisks, covered warmly and led back and forth several times in a sheltered place.

Yellow stains, which gray, white or dappled horses readily acquire from lying on filthy bedding can not be entirely or sufficiently removed by simple cleaning. To remove the yellow stains it is advisable to rub on a thin paste of charcoal powder, which after drying should be thoroughly brushed out. Simply covering the yellow stains with whiting is objectionable.

Unruly manes are braided with straw or string and dampened

frequently, then allowed to dry, and after that unbraided and brushed smooth.

The care of the skin of *cattle* is often sadly neglected. Very often the buttocks and tail are badly soiled with manure, which finally drops off in thick, dried layers. For hygienic reasons cattle should also be cleaned daily with a stiff (curry) brush, but without the use of the curry comb and if possible in a special room. Systematic care of the skin produces in milk cows an increase in milk secretion (according to Backhaus about 1 liter per head daily), so that the increased expenditure for systematic care of the skin, which is urgently demanded not only for veterinary but also human hygienic reasons, is thus compensated for. The udder should be so clean that no one would hesitate to touch it with his lips. The efficiency of fattened and work animals is also increased by proper care of the skin. With milk cows the care of the skin is greatly assisted by binding the tufted end of the tail with a cord and fastening it above (Fig. 191). This tying up of the tail still allows the cow to ward off flies and does not annoy her when lying down, but does prevent her from getting her tail into the liquid and other manure. For cows drenched in rain or snow the same treatment should be followed as prescribed for horses. It is also objectionable simply to lead wet cattle into the stable and leave them to dry without attention.

Hogs should also be cleaned or washed for hygienic reasons as well as to increase their ability for development.

Sheep are usually not cleaned because of their fleece.

2. *Washing and bathing.* If the legs are badly soiled with manure it is practicable to wash the dirt out of the hair. The water should be lukewarm at least during the winter. The legs should be rubbed thoroughly dry or bandaged after being washed (see p. 173).

It is also advisable to wash at longer intervals the mane, the tail, the sheath and the udder, as well as the entire animal. When washing the entire animal care must be taken that it does not catch cold. The animals are therefore generally not washed all over during the winter unless there is some special need of it (eradication of lice, alopecia areata and mange). Hard neutral curd soap (not soft soap!) may be used for the washing; however, it should always be rinsed off thoroughly. After this the animals should always be rubbed dry and kept warm or exercised in warm air.

An excellent and refreshing means of cleaning and stimulating the activity of the skin is bathing or "washing down" with a hose, which of course (except in the case of the small domestic animals) should be done only during warm weather, if necessary even daily, otherwise once or twice a week. The water for bathing should have a temperature of at least 18° C. (64° F.). The bed of the stream or

other body of water should not be marshy and the water should not have more than a medium velocity. The animals should not be bathed immediately after feeding nor while in an overheated condition, and should not be allowed to stay in the water more than 10 minutes. Horses should be rubbed off after bathing and should be exercised or covered warmly until completely dry. Cattle and hogs generally like to go into the water; this is less often true of horses. Bath basins or "wallows"[1] in the hog lot are especially desirable, as hogs particularly need bathing during the summer to regulate their body temperature. Animals with acute internal or rheumatic ailments as well as broken-winded horses (heaves) should as a rule be excluded from bathing.

3. *Shearing* or clipping removes a part of the heat protection and increases the heat-loss metabolism, appetite, and, in case of rich feed,

Fig. 113. Clippers.

increases the nutritive or fattening condition. Shearing also facilitates the care of the skin (important in case of skin parasites), hastens the drying of animals that have gotten wet, and prevents sweating, especially the so-called "after-sweating." It thus prevents colds and is a preventive for diseases resulting from colds. If, however, shorn animals can not be kept sufficiently warm nor be protected from cold rains, then the shearing, which robs the animal of a considerable part of its means of heat conservation, will have just the opposite effect, i. e., favor the development of colds immediately after the shearing. Since only the back and sides of horses can be protected against cold by blanketing, it is customary to shear only those parts of horses that can not be brought into warm stables immediately after hard work but must be left standing for a while in the open as, for instance, omnibus horses.

If pasture stock with thick coats are stabled after being taken off the pasture, they suffer from the heat even at a normal stable temperature of 15 to 17.5° C. (59 to 63.5° F.). By means of careful, thorough

[1]Preferably of concrete.—J. R. M.

ventilation it ought not be difficult at such times to keep the temperature lower (12° C., 53.6° F.). If, however, this can not be done because of the presence of other animals, it is then advisable to shear or clip such animals so as to aid in the loss of heat.

Entire shearing or clipping is usually suitable only for horses with thick, long hair and that must perform strenuous labor, particularly at the more rapid paces, and that can then be immediately protected against cold by being blanketed or being brought into warm stables (omnibus horses, etc.). On the other hand, the clipping that is customary to improve the appearance of carriage horses should be disapproved for hygienic reasons. Army horses are not customarily clipped because they may be called upon for campaigning at any time; at most, clipping is done when horses are poor feeders in order to increase their appetites. The clipped horses could not sufficiently withstand the weather inclemencies in the field. According to Gillet and Reynal, clipping experiments were conducted in the French army in 66 regiments with 1,254 horses (sickly, undernourished, soft, easily sweating, with long, thick hair, short-winded, ailing from skin eruptions or chronic bronchitis), and chiefly with good results. Sickly and soft horses improved, edematous swellings disappeared of their own accord, likewise skin diseases, and short-winded horses improved somewhat.

During the clipping the tactile hairs on the lips and eyes as well as the protective hairs on the inside of the ear concha should not be cut. Decided stumping of the tail hairs as well as docking is not approved from the hygienic standpoint, as the horses are thus robbed of their natural means of protection against flies.

The fetlock hairs should be shortened only when they have grown excessively long. If the hairs are cut too short they are very apt to prick the skin of the fetlock when the horse is in motion. Through continued mechanical irritation and surface injury an inflammation of the skin may result, then eczema, a disease commonly called grease. Besides this, the animals are robbed of their natural protection against wet and dirt, which naturally is conducive to sickness.

The clipping is usually done during October or November. The winter hair grows in from about the middle of September until the middle of December. The earlier the horses are clipped the faster the hair grows in, and vice versa. The clipping should, if possible, be done on warm days. After clipping, the animals should be vigorously rubbed with a woolen cloth, kept blanketed in the stable for several days, and carefully and thoroughly cleaned. Usually the clipping is done but once a year—though fancy horses are frequently shorn once more in the spring to remove the winter hair.

The hand clippers (Fig. 113) or the clipping machine (Fig. 114) should be used for clipping. Afterwards the animals should be carefully protected against colds.

4. *Blanketing the animals.* In order to prevent clipped animals or those that have gotten wet or are shedding, from catching cold when they have to stand in the open during cold, windy or rainy weather, or when they perform a service that does not involve great speed or exertion, it is advisable to cover the animals just as in cold, draughty stables, or as when transporting them by rail. In the case of work-horses a leather cover lined with light-weight wool is best for this purpose.

Fig. 114. Hauptner's clippers.

Special care should be taken when well-nourished horses are taken out of doors in cold, rough, windy weather after one or several days of rest in the stable. Under such conditions the horses should always be covered with a woolen blanket or a small lined leather loin covering, such as is used on coach horses, to protect them against the possibility of developing the very dangerous disease azoturia (hemoglobinuria) whose etiology has by no means as yet been explained. Furthermore, the grain ration should be reduced during days when horses are not working.

Likewise animals that are shedding, during which time the skin is more or less hyperemic, need careful attention to the skin and protection against colds. They should be worked sparingly and given slightly laxative but nourishing feed (carrots, linseed cake and young green feed as additional feed). During their spring shedding the animals are particularly weak, less capable of resistance and more

inclined toward disease. The changing of hair coat is distinctly noticeable only in the case of animals that are exposed to change of weather.

However, in the absence of good reason horses should not be blanketed, as this weakens them and they become more susceptible to colds. This is true of fancy horses which are kept blanketed in the stable a great deal of the time in order that they may have a tender skin and a smooth, glossy coat.

Besides the blankets which are used for protection against cold and rain, there are also linen (less often cotton) covers or net covers and ear tabs which are used during the summer to keep off insects. The use of these is to be recommended for hygienic reasons. The same is true of the straw hats used on horses to protect them from the hot sun.

II. Care of the Legs, Hoofs and Horns

It is extremely advisable that special care be given to the legs of horses. The legs are particularly subject to being soiled and they ought therefore to be groomed after each day's work to avoid skin diseases. Ordinarily the legs should not be washed too often; the

Fig. 115. Regular or normal front foot of a beef. (After Pusch.)

Fig. 116. Rolling foot. (After Pusch.)

constant action of moisture causes the skin to chap and become cracked, allowing the causative agents of disease to gain entrance. If the legs are dry when horses return, they may be cleaned with a brush, a bunch of straw or hay or a woolen cloth. Mud or wet dirt should be washed off with lukewarm water. After this the skin should be rubbed thoroughly dry. Ordinarily the legs are rubbed dry with soft hay or straw or with woolen cloths and the dirt brushed out. During cold wet weather the fetlocks and pasterns should be rubbed with grease to keep the filth and melted snow off the skin.

After severe exertions the legs should be rubbed with straw, hay or cloths. This massage promotes the circulation of blood and lymph, arrests congestion, and therefore prevents swellings and the formation of galls. After exceptionally great exertion the Priesznitz compresses are used or the legs are bandaged (Fig. 185). Continued bandaging, however, is objectionable; it is advisable to reserve the bandaging for special occasions. Bandaging is also useful in the

treatment of diseases of tendons, tendon sheaths and joints, as well as in the prolonged idle standing of fancy horses in their stables, particularly during their shedding period and when changing feed. Furthermore, valuable horses are bandaged during transportation by rail, also horses for steeplechases and hunting horses which leap over stationary obstacles, in order to protect them against injuries and contusions.

The *care of hoofs* is very important for work animals, for it affects not only the condition of the hoof but also the position of the leg, and in this way the efficiency and value of the animals are also greatly influenced.

Proper care of the hoofs includes giving the animals clean, dry bedding. Dirty stables are even worse for the hoofs than swampy pastures. Shod as well as unshod hoofs should be cleaned daily (and

Fig. 117. Neglected colt's hoof. *a*, A foal's hoof that is too long and too pointed, the bulbs of the heels shoved under and the foot's axis bent backwards. *b*, Bottom of hoof represented under "*a*." The wall which is too long is bent over at the heels; the frog becomes contracted (foal's contracted heels). *c*, Foal's hoof having too high heel wall, brittle bearing surface and the toe's axis bent forward. (From Gutenaecker-Moser, "The Teachings of Horse Shoeing.")

the toes of cloven hoofs from time to time), i. e., all particles of dirt on the sole, in the medial cleft of frog and in the hollow space between the shoe and the sole should be removed with a hoof scraper, a slightly pointed piece of wood, and the sole and wall rubbed with grease. The hoofs should now and then, and always when very dirty, be cleaned with a stiff brush, cold water and soap. After the hoof has been thoroughly dried it should be greased to prevent it from drying out. For greasing, vaseline free from petroleum should be used. Animal and vegetable fats and oils easily become rancid and then irritate the coronary band just as vaseline containing petroleum will do; inflammation with the formation of a bark-like horn frequently develops. During continuous rainy and slushy weather it is advisable to add a little wax or thick turpentine to the vaseline and thoroughly grease the walls and soles of the hoofs. Special hoof salves are unnecessary; they do not influence the growth of the hoof. The vaseline is best rubbed in with a cloth or tow-pad. With the

usual practice of using a brush a thick layer of grease remains, upon which dirt settles that may injure the hoof.

Rubbing the sole and frog with tar is usually not necessary. Tar is used successfully and beneficially only in case of cushion pads, loose wall and decayed frog, etc., as prophylaxis against processes of decay.

To prevent the horny wall of the hoof from drying out too much during drought, it may become necessary to cover the front hoofs with a clay paste, which must be kept moist, or with damp sawdust, or to stand them in water (the hoof of the hind feet is kept damp enough with the urine and feces). After this the hoofs should be dried and the sole thoroughly greased; otherwise the horny hoof will become especially hard and brittle.

Cushion pads (rubber cushions, straw soles, etc.) are usually not necessary for healthy, normal hoofs; nevertheless they make it possible for the sole and frog to come in contact with the ground and accordingly support the normal hoof mechanism and the blood circulation. They also prevent the snow and ice from packing and consequently aid materially in preventing horses from slipping. In order that sanitation of the sole and frog may not suffer through these attachments, it is advisable to remove these protective pads in the stable and to rub the hoofs with tar, as otherwise the stagnating filth under these cushion pads decay, and the less resistant horn of the frog becomes affected and finally more or less falls prey to decomposition processes (frog rot).

Another very important factor in the care of the hoofs is exercise. With unshod hoofs (both single and cloven) this treatment generally suffices while the animals are kept out in the open.

In preparing the hoof for going unshod, the horn of the frog should be cut down level with the bearing or supporting surface; the wall, if too long, should be shortened, and the outer edge should be rounded off. The old nail holes should be closed with putty or grafting wax to prevent decay in the wall of the hoof. Whatever horn grows in the course of time on the bearing surface of the sole and frog is usually worn off in walking. If this wearing off should not keep pace with the growth or not follow up evenly, the rasp should be used.

When animals are confined in stables for a long period, unshod hoofs absolutely require care. With due consideration to the position of the animal, the horny wall must be shortened every 4 or 5 weeks until the bearing surface is level with the compact horn of the sole near the white line. The outer edge of the bearing surface should be rounded off considerably with the rasp. The horn of the sole and frog should not be treated severely; only the loose shreds and crumbly pieces should be removed (Fig. 118).

The hoofs of colts raised in the stable should be given special attention (Fig. 117). Hoofs that have grown crooked should be brought back to their normal shape. By this means the development of wrong positions (hoofs too wide or too narrow at the bottom) can be avoided, or defects that have already begun to develop can be rectified. In the case of young foals born with defective positions such defects can to a certain degree be improved by suitable cutting or trimming of the hoof.

Cloven hoofs should also be shortened about every three months, so that the weight of the body does not rest too heavily upon the balls of the feet, because the pain resulting from this will cause a cramped walk and position (Fig. 116). In the case of bulls the pains can even cause them to refuse to cover, especially if the service is to be done on a hard floor.

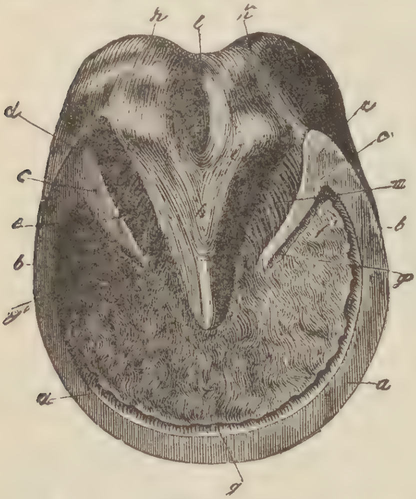


Fig. 118. Normal hind foot seen from the ground surface. (Lungwitz.)

Fig. 119. Normal shod fore foot. (Lungwitz.)

As long as it is possible to manage without shoeing it is best to leave both single and cloven hoofs unshod; for every shoeing has its disadvantages, as it causes injury to the hoof mechanism and consequently to the blood circulation in the hoof. Young horses should certainly not be shod until they are to be used for work on hard streets, which should never be done until they are 3½ to 4 years old.

Good shoeing is of the greatest importance in the care of shod hoofs. In this connection the following points are to be observed:

After the old shoe has been removed the horny hoof which has grown too long should be trimmed off with the rasp and grooving knife, bearing in mind the position and gait. Then only the brittle "dead" horn is removed from the sole (Fig. 118-f), after which the wall's bearing surface (a) is cut down so far that a margin of the horny sole, about the width of a blade of straw, still comes within the so-called supporting surface of the hoof. Since the toe wall of the shod hoof wears off against the shoe less than the quarter wall

(which carries the weight) the toe wall should be shortened correspondingly more.

After properly trimming a normal hoof, which is all that can be discussed here, the side view of the toe wall and the pastern should run in a straight line. The height of the hoof wall is furthermore regulated, in that the side which first touches the ground in stepping off, or whose shoe branch is worn down the most, is usually kept lower. Along the frog (h and i) only loose horny particles should be removed. The same should be done with the bars (c), which should be left at about the same level as the bearing surface of the wall; only the branches of the sole should be kept about 2 mm. ($\frac{1}{16}$ inch) lower.

The outer surface of the walls of sound hoofs should never be rasped. The sharp edge of the bearing surface of the hoof should be scraped off with the rasp in such a way that the real strength and thickness of the wall is shown.

Regarding shoes, from a hygienic standpoint, the plain horseshoe (especially the half-moon shaped shoe) is preferred, since it is least injurious to the hoof mechanism. The shoe should be narrower on the ground surface than on the hoof surface and not too heavy. Its bearing surface should be absolutely horizontal and as broad as that of the hoof. Lungwitz writes: "The shoe should always be made according to the shape of the hoof as long as it is unchanged. With hoofs that have changed their shape one should endeavor gradually to bring the shoe to the shape which the hoof possessed before it became changed (when it was sound)."

In attaching the shoe care should also be taken that the nails (which in the front shoe are arranged in the front half of the shoe, and in the hind shoe in the forward two-thirds part of the shoe) penetrate the hoof on the white line (g) and do not injure the soft parts of the hoof.

Sound hoofs should not be shod oftener than every five weeks.

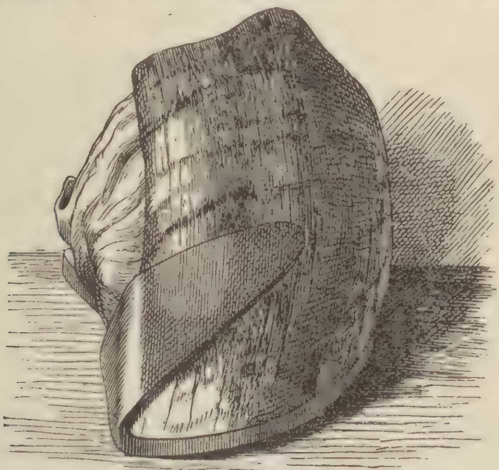


Fig. 120. Shod ox claw. (After Lungwitz.)

If the *hoofs of work oxen* must be shod we must bear in mind that the foot of the ox is cloven and that each half is provided with a special horny capsule. In walking the two halves of the feet or the two toes spread apart, which results in partly breaking the shock or jar when taking step (which is accomplished in horses by the frog and the frog cushion and by the expansion of the horny capsule). In shoeing cattle each half of the hoof must be shod with a separate shoe; both halves should not be shod together with one shoe. The

latter method of shoeing is practicable only when the ground is very uneven, as, for example, frozen or rocky ground.

Since the wall and sole of the hoof of cattle are decidedly thinner than those of the horse's hoof, the shoe for the cloven hoof must be broad and thin, with shallow holes, and must be provided at the toe part of the inner edge of the shoe with a long feathery end, which is bent outward over the point of the half hoof and materially aids in holding the shoe on the toe (Fig. 120).

Fig. 121. Horn directors.

Finally, the *care of horns* must be considered. The horn should be blunted enough to render it useless as a dangerous weapon[2]. The sharp point should be sawed off, the edges rounded off with a file, and the horn slightly greased. Horns are trained into the desired position by means of horn adjusters (Fig. 121), particularly in the case of animals that are valuable for breeding purposes.

III. Land and Sea Transportation

In the transportation of livestock on land, if it is impracticable to drive them on foot, and if no special vehicles[3] are available, the animals may be loaded on wagons (or sleds). If the animals can not stand they should be tied.

The animals should be fed sparingly shortly before and during transportation; this applies equally to transportation by rail or by ordinary road.

If there is any difficulty about loading, the quiet animals are allowed to go first. The stubborn animals should be handled quietly, led up close behind the first animals, or should be coaxed with hay or be led backward into the wagon or car. Sometimes blindfolding the eyes or the use of a whip will help. Some horses shy at the railing of chutes but go willingly over plain boards. Wrangel recommends that a heavy rope be placed around the knees of a stubborn horse and that he be pulled into the car. The tails of horses should be braided with straw before shipment. An attendant should accompany the horses and not leave them during stops at the various stations[4].

[2]Methods of dehorning cattle are described in Farmers' Bulletin 949, U. S. Dept. of Agriculture.—J. R. M.

[3]In the United States special cars are provided for the transportation of livestock by railroad. —J. R. M.

[4]In the United States there is a Federal law which provides that livestock must not be confined in railway cars longer than 28 hours (except under certain circumstances) without being unloaded for feed, water and rest. The Railroads have to provide suitable facilities.—J. R. M.

Livestock on board ships must be accommodated so that they do not interfere with the work of the ship, the ventilation, or the manipulation of the lifeboats, but on the other hand so that the animals can not be injured[5]. The space that should be allowed for animals is as follows: For a horse, 2.45 by 0.70 to 0.75 meters (8 feet by 2 feet 4 to 6 inches); for a mule, 2.20 by 0.55 to 0.60 meters (7 feet 2½ inches by 1 foot 9 inches to 2 feet); for an ass, 2.20 by 0.50 to 0.55 meters (7 feet 2½ inches by 1 foot 8 to 9 inches). The smaller measurements refer chiefly to deck space, the larger ones to middle-deck and cargo space. Inclosed spaces should be at least 1.85 meter (6 feet) high and should have enough openings for entrance of fresh air and sufficient mechanical ventilators to carry off the stale air so that 12 cubic meters of fresh air is admitted hourly into the space for every head of large cattle and 1½ cubic meters for every small.

If the provisions for ventilation are not satisfactory, air pipes about ½ meter (1 foot 8 inches) in diameter are constructed of sail cloth and are provided with a pair of wings above to catch the air. Cattle should not be placed near furnaces and steam boilers unless their space is separated from them by a firm double wall with 10 cm. (4 inches) of space between filled with sand and erected 10 cm. distant from the wall of the machine room.

Animals should be fed sparingly for several days before embarkation. If the horses have to be led aboard from the quay or pier across a gangway, the latter should be strewn with sand or straw and the horses should be blindfolded. Long bridges should be provided with solid walls on both sides. If the horses are brought aboard by means of cranes, a layer of straw should be put down on the loading place. Loading from smaller steamers or lighters should be done in padded boxes of very firm construction. To prevent sprains and broken bones the boxes must be lowered very carefully.

The animals should be placed with their heads toward the gangway and with their hind quarters against the padded tailboards so that they will have support in case of a rough sea. Partitions between stalls are sometimes made of smooth boards padded with straw and sailcloth at the body's height; these afford the animals a hold. During a high sea it is advisable to provide another board in front of the chest and at the height of the hocks. Before loading the animals should be examined by a veterinarian[6].

In front of each row of cattle there should be a corridor at least 50 to 70 cm. (20 to 28 inches) in width and between two rows of cattle one of 70 to 80 cm. (28 to 32 inches).

For a cavalry regiment (660 men and 613 horses) a ship of 10,310 tons must be allowed; for a battery of 6 cannon 3,000 tons.

The feed troughs shoulds be fastened securely! The animals should be tied and should be provided with sufficient bedding to make them comfortable. Peat is recommended for bedding.

The feed that is taken along (preferably hay, for a large animal daily about 10 kg. or 22 pounds) should be of good quality. The quantity should be estimated so that it will last 2 to 5 days longer than the voyage, according to its length, and possible quarantine. The feed can be stowed on deck for only 12 days. If the voyage lasts longer the remainder must be placed below deck. At least half of the water supply should be taken along in tanks; the rest can be supplied by condensation. If the instructions mentioned on page 93 are not followed the condensed water should be stored for at least 48 hours in the cooling tanks before using it. Freshly distilled water is injurious to the health. Forty-five liters (quarts) of water daily is figured for each head of large animals. During longer sea voyages horses should be exercised daily on the exercising deck, which should be covered with coco matting, sand or peat. During that time the stalls should be cleaned and aired. Feces and liquid manure should, if possible, be removed. Electric lamps should be used for lighting.

[5]The ocean transportation of livestock from the United States to other countries is governed by Federal law and by regulations of the Secretary of Agriculture which prescribe the fittings and facilities considered necessary for the safety and proper care of the animals.—J. R. M.

[6]Official veterinary inspection is required before exportation from the United States.—J. R. M.

B. The Management of Animals

Vices or *bad habits* can occasionally lower the usefulness of animals and at times even actually render them of no use whatever. By means of quiet, orderly treatment of animals that are naturally good natured the development of vicious habits may be prevented. Vices once acquired are very difficult to overcome. The following vices are found predominantly in horses:

Little vices generally arise through lack of work and from bad examples. The most common tricks are clattering with the incisors, playing with the halter, whetting the incisors on a rail, teetering or "weaving" (moving back and forth from one forefoot to the other), putting out the tongue, hiccoughing, etc. Hard work that will cause fatigue sometimes helps to break the animals of such habits.

The *weaving* or *teetering* habit can occasionally be stopped if leather straps are used for tying in place of the clanking iron chains, or if the animals are placed loose in the stalls. This latter remedy also is often of great help in stopping pawing with the forefeet.

Hiccoughing (gasping, wind-sucking, cribbing) consists in the horse swallowing air and then ejecting it audibly. The causes given for this habit are the example set by other horses, ennui, hunger, stomach disorder, longing for salt, wooden cribs without metal mountings, etc. Many ways are suggested to stop this hiccoughing habit, as, for example a special bit, painting the front edge of the crib and other places of contact with green soap, fastening on an iron muzzle, etc. A remedy more worthy of recommendation is the hiccoughing straps which are adjusted so that the horse can swallow but can not draw the larynx downward, i. e., it can not hiccough. A certain amount of success can be gained during the first stages of the affliction by providing strenuous work, dividing the daily supply of feed into 6 to 8 smaller rations, by providing sufficient good litter, by giving some palatable oat straw for nibbling during the long night rest, putting in a snaffle bit with an appendage for diversion during the daytime.

The *tearing of covers* by horses can be prevented by means of a muzzle as well as by means of a special stick or halter fastened between the halter and blanket strap or by a chain muzzle (Fig. 122).

Backing and *putting all his weight on the halter* can result in the horse falling if the halter or strap should break. The best remedy for this vice is a heavy rope placed across the nose and put through the halter loops and then tying the horse fast. Undue backing will thus exert a painful pressure on the nose.

Fear. Some animals shy at certain objects, (white paper, water [so-called ground shying], steam rollers, automobiles, etc.), which other horses pass unnoticed. The frightened horse jumps aside, rears up, or runs away. Confidence can be instilled into the horse by often

leading it quietly past the feared object and accustoming it to its appearance by gentle treatment and not by blows, thus convincing it that its fears are unfounded.

Other animals are afraid to go through strange doors, particularly smaller doors. In this case again kindness, coaxing with hay, oats, etc., accomplish the best results and most readily break the animal of this form of fear.

A muzzle is only a provisional means of preventing *biting,* since it must always be removed during feeding, etc. With patient but energetic attention—a vigorous blow at each attempt to bite—this vice can be corrected, but frequently only in regard to the instructor and not toward strangers.

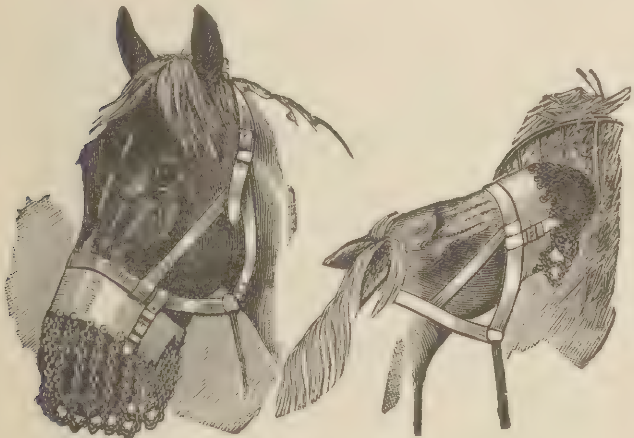


Fig. 122. Chain muzzle for horses that eat blankets.

Fig. 123. Wooden ball as anti-kicking device

In case of *kicking,* attention should be given first to see whether it is not being caused by itching due to lice or foot mange. If they are present, they can easily be cured by rubbing with blue (mercurial) ointment, etc. Ample work is a good cure for the kicking habit. Sometimes it is also advisable to fasten a wooden ball (**c** in Fig. 123) to the lower leg so that it will rest upon the metatarsus (shin bone). Every time the horse kicks the ball will immediately punish it.

I. Draft and Work Animals

For drawing and carrying loads (horses, donkeys, mules) are to be considered first, then draft oxen, and lastly cows. In order not to impair their efficiency and to prevent premature wearing out of the animals they should not be started at heavy work when too young.

Farm horses are usually put to work after the third year, beginning with light half-day work, followed later with work the entire

day, and after the fourth year they are started at heavy work. Heavy, early matured draft horses should not be used even for light work before they are 3½ years old and not for heavy work until 4½ or 5 years of age. The warm-blooded horses (wagon horses) which mature more slowly should not even be used for light, short drives until they have reached 4½ years of age; not for strenuous service until after the fifth year, and not for full heavy work until the sixth year has been reached. The same is also true of riding horses. Exception is made only with race-horses; they are often allowed on the race-track after the second year.

Draft oxen may be put to work when three years old, but should not be given the maximum amount of work before the fifth year.

Making too early and too great demands on their strength will cause all draft animals to wear out too soon and to develop diseased conditions of the bones, joints, ligaments, and tendons (spavin, ringbone, splints, wind galls, joint galls, dorsal flexion of fetlock joint, stilty leg due to ankylosis of the lowest three joints, lameness, etc.). Race horses often give proof of this.

Breaking and training the animals for service must be done quietly and patiently. Mistakes easily lead to insubordination (refusal to move, plunging and bucking, kicking over the traces, etc.). If such habits have been formed they are very difficult to break. Results can be best obtained with such animals (which usually have also been beaten) through kindness, exhorting, giving bread and sugar, absolutely not using the whip, undertaking the very lightest work and leading the horse by the head while talking encouragingly to it; then amount of work can be gradually increased and the horse led by a longer rein. To break wagon horses of refusing to move (balking), Johne gives the following procedure:

"A well-fitting harness is put on the horse and a rope 3 to 4 meters long is tied to the end of each of the traces, each of which is held by a man. The horse is then carefully led out while the two men follow quietly with the loose traces behind the horse. Gradually and very carefully they pull the traces taut so that the horse gradually feels a certain amount of resistance. This is increased only by a very gradual tightening of the traces, until at last the horse quietly pulls along the men hanging firmly on the traces. At intervals the horse should be stopped and then made to start pulling quietly again. If this task is accomplished without resistance, it can be increased in the same quiet manner by having two, three, or even four men instead of one hold on and letting the horse pull these. If in this way the horse can be convinced that the weight hanging on its harness can be moved without much difficulty and if it has also gradually become accustomed to being led by a long rein, then after one or two days it will be possible to hitch the horse to a light wagon.

"In doing this the following rules, which usually are not sufficiently observed, must be followed:

"1. The horse must not be allowed to see or feel a whip.

"2. The horse must, on the other hand, always be led slowly by the head. It cannot be led by a long rein nor driven from the wagon until later.

"3. All the attempts must be made only at a walk during the first two days, during which the horse should be stopped at intervals and then quietly started again. Changing to a slight trot while driving must be done very

gradually at first. After that several persons can get into the carriage to increase the weight of the load.

"If this procedure is followed gradually and patiently, and if care is exercised not to strike at the slightest stubbornness that the animal may show, but instead rather to diminish one's demands, and if, instead of spending only a few hours with such a system, as many unsuccessfully attempt to do, days or even weeks are spent, then (according to the experiences of the author) there will hardly be found a case of stubbornness that can not thus be cured."

Zuern recommends putting the horse into the stall harnessed, then fastening a singletree to the traces and to this a rope running over a firmly fixed pulley. To the other free end of the rope heavy weights should be fastened. If the horse, which is then standing away from the manger, wants to eat, it must first lift the weight and keep it up. The weight that is to be lifted should gradually be increased.

The work exacted of the animal should not exceed its strength; overexertion should be avoided. As an average amount of labor for a heavy work horse on a level, solid road we can reckon a load of 30 to 40 cwt.; for a medium heavy or ordinary wagon horse a 20 to 25 cwt. load (including the wagon). Such work can be done, with suitable pauses for resting and feeding, from 8 to 10 hours daily. At a more rapid pace the load should of course be lessened considerably. Light-weight, warm-blooded wagon horses can draw a load of about 4 cwt. at a good gait, and with intervals for resting and feeding, for 8 hours daily; medium heavy wagon horses about 10 to 12 cwt. for about 5 hours daily at a half trot. Medium heavy riding horses can carry a weight of about 80 kg. (175 lbs.) for 8 to 10 hours and cover a maximum of about 80 to 100 kilometers (50 to 62 miles) at a moderate pace on a level road with proper resting and feeding pauses. At first 1 kilometer (nearly two-thirds of a mile) should be ridden at a walk, then 1 to 2 kilometers (two-thirds of a mile to a mile and a quarter) at a trot, so that 8 to 10 kilometers (5 to 6 miles) are covered in an hour. During longer marches a resting pause should be made every 10 kilometers (6 miles). In traveling over steep roads it is a relief to the horses as well as to the rider to lead the horse; likewise during excessive heat a temporary leading of the horse is refreshing to both rider and horse. To save the strength of the horse two old proverbs are worth considering, namely: "Walk out of the stable and walk into the stable." "Spare me up hill; lead me down hill; on the level use me and let me run." Horses should be exercised daily if possible. During resting days they should be led about at least half an hour to one hour to prevent hemoglobinuria (azoturia), and well-nourished animals should also be fed sparingly.

Continuous and strenuous work should be interrupted by intervals of rest and should not be continued to the stage of exhaustion. Work that is of long duration is usually interrupted after 2½ to three hours by a pause a quarter to half an hour. In the case of a horse going at a rapid gait, ten minutes of trotting and five minutes of galloping may be alternated with a walking pace, and a stop is made every 1 to 2 hours, according to the animal's strength and amount of

strength consumed. About 2 hours should be allowed for the feeding of the horse, and 3 hours for ruminants.

Mules as draft animals should be considered the same as heavy horses, etc. As beasts of burden they are given a load of an average of 90 kg. (200 lbs.) a maximum of 130 kg. (285 lbs.) to carry.

Draft oxen may be used at work for 10 hours daily. In order not to diminish the milk yield, cows should be encouraged to do only a very moderate amount of work. They should not be forced to do draft work 3 or 4 weeks before and 4 or 5 weeks after calving. Gentle draft work often proves itself to be wholesome for many excitable but otherwise healthy cows and heifers which in spite of repeated covering do not conceive. Even bulls intended for breeding purposes are often used as draft animals in some localities to give them the proper amount of exercise. If overexertion is avoided, this practice can be approved.

After exceedingly strenuous labor especially good treatment should be given the animals. For this purpose warm foot baths, Priesznitz compresses up to above the knees or hocks, or bandages are recommended. To avoid overfeeding after very strenuous work the feed is given in small portions but without stinting the entire amount.

The Priesznitz compresses are applied as follows: The legs are carefully washed and then bound from the coronet of the hoof to above the hock with a linen bandage 5 to 7 cm. (2 to 2¾ inches) in width and 2 meters (yards) long which has been dipped into cold water and then lightly squeezed out. Over this a woolen bandage 10 to 12 cm. (4 to 5 inches) wide 2 to 3 meters long, is bound more tightly in close spiral revolutions. These compresses, which should be renewed every 3 or 4 hours, are still more efficacious if gutta percha paper or other waterproof material is placed between the linen and woolen bandages.

The ordinary bandaging is done after previously washing and rubbing the leg dry in the following manner: The legs are wrapped in spiral revolutions from the bottom upward with flannel, or, even better, with elastic bandages. The loose end of the bandage is sewed down in a three-cornered manner and two tapes about 30 cm. (1 foot) in length are sewed to it. With these tapes the bandage is finally fastened, but not too tightly.

While changing the Priesnitz compresses and the bandages the legs should be rubbed down (massaged). This kind of special treatment aftter severe exertion prevents the development of tendon and joint galls (swellings) and preserves the animal's efficiency.

Overexertion should be avoided. It may cause paralysis of the heart (heart failure), hemorrhage in the lungs, interstitial pulmonary emphysema (heaves) and the various ailments of the locomotory apparatus (tendo-synovitis, ruptured and inflamed ligaments or tendons, splints, spavin, ringbone, galls).

In order that the work rendered by draft animals may be turned to account most profitably it is necessary that the wagon and the harness be properly constructed and arranged so that all injury to the animals is avoided.

The weight and size of the *wagon* should be suited to the draft animal and to the load that is to be moved. The singletree should be

kept wide enough so that the traces do not rub the sides of the horse's shanks. The doubletree should be movable so that the work of each animal can be watched and regulated. The shafts or wagon pole (tongue) should be long enough to prevent injury to the draft animals from the wagon which is following. The front end of the shaft should be about level with the shoulder joint. Shafts that hang lower must be carried by means of the breeching and may cause chafing and bruises on the upper part of the neck from the horse-collar. Shafts that are too high strike against the animal's head. In hilly country the wagon should be provided with a brake so as to prevent the horses from becoming chafed on the upper part of the neck and to avoid a strain on the forelegs (joint and tendon trouble). The breechings must be long enough for the horses to go forward in a straight line. If the breeching is buckled up too short (in the case of coach horses) the horses will go crooked and consequently strike themselves easily (on the legs). The elastic spring protectors (Fig. 124) that are inserted between the singletree and the end of the traces

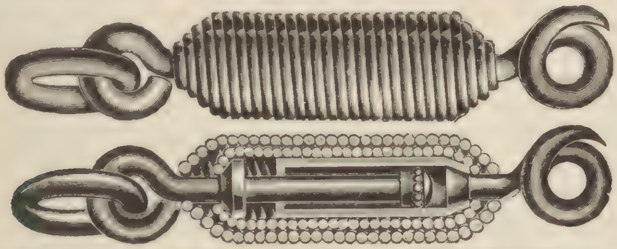


Fig. 124. Horse protector with ball bearing (as shock absorber).

break the jar when stopping with a heavy load as well as when pulling a load on uneven ground. They therefore save the strength of the horse, avoid bruises and torn tendons, and lessen the possibility of horses falling on slippery ground. They furthermore offer the advantage of causing horses that shy to pull better. The elastic singletrees serve the same purpose. If the protectors and elastic singletrees are to serve their purpose fully the spring must not be allowed to reach its limit with heavy loads and jerky pulling, and it must be strong enough so that even then its elastic action is retained. The springs should not be too heavy.

The *harness* must fit well and uniformly to prevent scrapping and bruises. The harness with a horse collar is preferred for hilly country. The weight of the load is thus more evenly distributed over the chest, shoulders and withers and the harness fits more firmly and does not cause chafing so easily. These harnesses have the disadvantage of not always having a collar that fits every horse or that can always be made to fit, even though the newer adjustable collars have greatly helped to overcome this fault. To make the collar fit comfortably on a heavy work horse a well-made collar-

shaped cushion stuffed with horsehair is placed under the collar of the harness. In level country the harness with a breast piece (Fig. 125) is used more. It is decidedly lighter in weight and generally fits better; only with horses that have a low-set neck and projecting shoulder joints do the breast pieces press lightly on the windpipe and hinder free movement of the shoulder joints. They have the disadvantage of not distributing the weight evenly and act chiefly upon the front part of the chest. Above all, care must be taken that the harnesses with collar and breast piece fits well so as to produce no injury from pressure, and that the surface that is in contact with the skin is kept clean. These parts of the harness should be cleaned before being used on other horses, and disinfected if necessary, since disease germs, pus-producing bacteria, tumors (botryomycosis) and glanders may easily be transmitted by these very parts of the harness.

The collars should not be too heavy. Light-weight collars for fancy horses should weigh only 3 kg. (6½ lbs.), heavy ones 5 or 6 kg. (11 to 13 lbs.), and those for work horses about 6 to 9 kg. (13 to 20 lbs.). Heavier collars should exactly fit each horse. Such a collar should rest on the shoulders and along the spine of the scapula but should not extend over this ridge. The main pressure during pulling should fall on the middle portion of the anterior supraspinous muscles and on the ridge of the shoulder blade. The collar should be sufficiently broad at the withers and should fit loosely, not pressed tightly, so that the horse does not chafe while walking and that no bruises result. The lower part of the collar should be wide enough to allow play of the width of two fingers between the collar and the chest when the animal is at rest or in action. The horse should be able to move its neck freely and there should be no pressure either on the windpipe or on the jugular vein. In order to keep the collar in its proper position when drawing a load, the collar and martingale must be properly adjusted, the traces must be of the same length, and the belly band must be of the correct length. The collar or collar cushion should be most heavily padded where it rests firmly on the horse.

If the horse is not built symmetrically in the shoulders, withers and sides of the chest, which is often the case, these deviations should be noted and the collar made to conform to them.

The buckle or cramp iron into which the martingale is fastened must be located about in the middle of the side pieces of the shoulder-blade portion of the collar. Adjusting it too low, which is often done, prevents the collar from lying flat against the ridge of the shoulder blade when the horse is pulling a load, presses the chest portion of the collar against the fore part of the chest, and raises the collar peak forward, which is especially objectionable with large or heavy pointed collars. To guarantee a good fit of the martingale, an

arrangement is recommended that allows the martingale to be raised or lowered on the collar.

Some collars are rigid, while others are adjustable in length and breadth so that they can be fitted to the horse for the time being. The latter are in general to be preferred. A distinction is furthermore made between pointed collars and English collars (without a peak). The latter are cheaper and lighter in weight and therefore usually deserve the preference. On the other hand, well-fitting, nonadjustable pointed collars are to be preferred for heavy work.

Collar pads or cushions are not necessary if the collar is well padded; however, they have the advantage of being kept clean more easily and may be cleaned and re-upholstered at less cost than the collars.

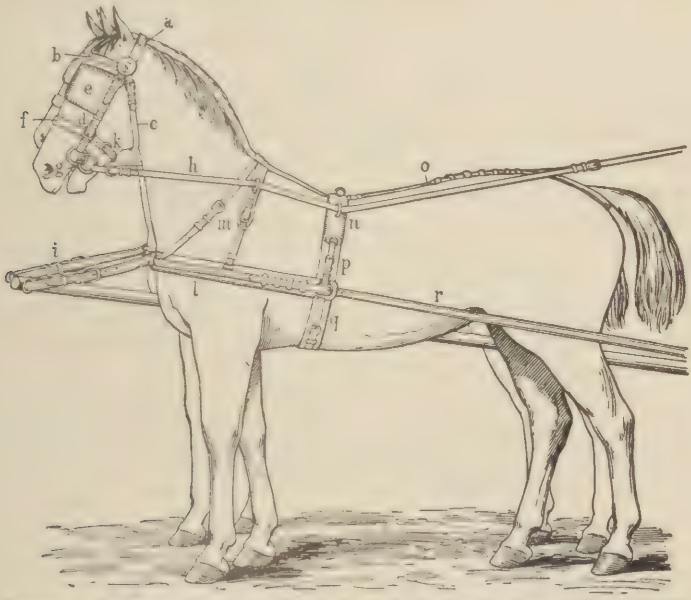


Fig. 125. Harness with breast piece. *a*, Head piece; *b*, forehead strap; *c*, throat latch; *d*, cheek strap; *e*, blind; *f*, nose strap, *g*, bit; *h*, rein; *i*, wagon pole straps to collar; *k*, jaw strap; *l*, breast piece; *m*, withers strap; *n*, harness saddle; *o*, back strap and crupper; *p*, back girth; *q*, belly girth; *r*, traces.

The traces (Fig. 125) should not be made longer than necessary. The best position for the traces leading from the wagon to the horse is an absolutely horizontal one that runs parallel with the ground and with the tongue of the wagon. With absolutely level ground this assumption is correct; but the ground is not absolutely level, and to overcome the unevenness the traces should best be given a pitch or slope from the horse backward and downward. For this reason the traces are usually fastened to the wagon below the tongue or shafts.

The back and belly band (Fig. 125, p and q) must support the side straps, keep them in the position most favorable for hauling, and

prevent the harness from shifting and allowing the side straps to fit loosely. The back band is usually connected with the collar by means of the back strap. The latter, together with the crupper (o), which extends backward and under the tail, serves to keep the collar in its correct position when the horse is stopped or is being backed. On top is the harness saddle (n) with checkhook for the checkrein as well as rings for the driving reins. Sometimes a martingale is buckled to the belly band. In single harness the saddle is made stronger, and for heavier cart horses it is elaborated into a pack-saddle or saddle and is provided with loops for carrying the shafts.

The rear harness or rear part, which is generally lacking in a fancy harness, consists of the breeching or breeching body and the breech straps. The breeching should pass around the buttocks about the breadth of a hand below the tuber ischii. The breeching ends at the side parts of the saddle or in the upper portion of the belly band. It is held by two pairs of supporting straps, the breech straps, which pass over the haunches or rump and connect with the crupper. The rear part of the harness serves as a check and for backing heavily laden wagons. (The breech strap is fastened to the shafts.—Translator's note.) The wagon-pole straps can not act as substitutes for the rear part of the harness. These straps (i), however, are satisfactory for lighter loads. They must be left long enough that the fore part of the horses' bodies are not drawn toward the tip of the pole and brought out of their proper positions. (This is often seen with fancy horses and easily causes interference.)

The parts of the harness with collar or breast piece are shown in Fig. 125. The wagon-pole chain is often fastened to the breastband when the neck strap is omitted. The position of the breast strap (l) is above the shoulder joint, just barely covering it. For the separate parts of the head harness see Fig. 125. Of the different types of bits the ones to be preferred for all young horses and for such older ones as still retain normal sensitiveness are the thick round bits with a joint in the middle; they prevent bruises of the mucous membrane and tongue. Spiral bits are suitable only in case of insensitiveness. Bits without the joint burden the tongue very much and often cause a stretched tongue.

Checkreins should be avoided with all farm and other work horses. Their use should be limited even with coach horses, and they should be used only with such horses as naturally carry their heads and necks high.

Blinders should, if possible, be avoided entirely. They act only as annoying wind and dust catchers, which unnecessarily force the animals into an uncomfortable forward position of the axis of vision without preventing them from shying. It is, however, almost impossible to manage without blinders in case of very spirited, timor-

ous horses, as well as when driving a team the horses of which have different temperaments. The blinders should be placed so that they

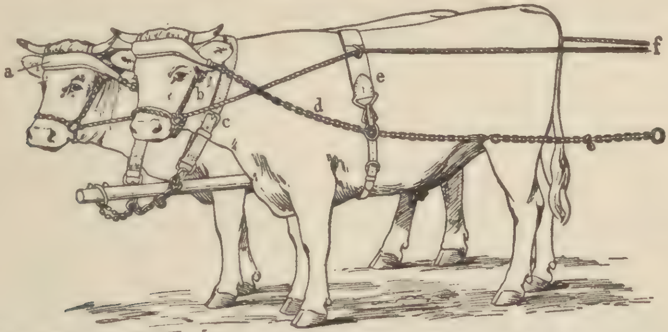


Fig. 126. Head Yoke. *a*, Forehead yoke; *b*, bridle; *c*, neck strap with supporting or steering chain; *d*, tug chain; *e*, back and belly strap; *f*, rein.

do not obstruct the view to the front or side but shut out the view at the back. They can be kept away from the eyes sufficiently by

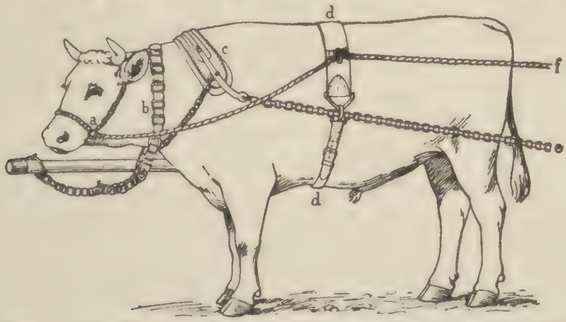


Fig. 127. Neck Yoke. *a*, Bridle, *b*, neck strap with supporting or steering strap; *c*, neck yoke; *d*, back and belly strap; *e*, tug chain; *f*, rein.

stiffening the leather with inlaid wire, or they are made in the shape of narrow blinders that project to the side. In Berlin blinders and

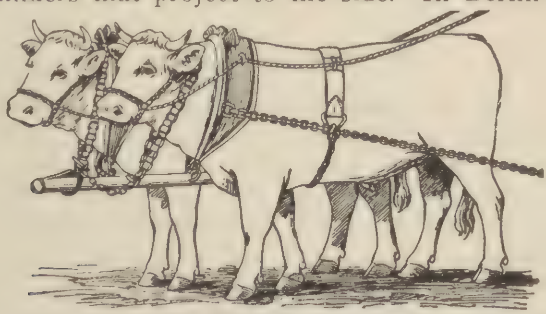


Fig. 128. Collar harness.

checkreins are forbidden by the "cab order." In Saxony only close-fitting and poorly adjusted blinders are forbidden.

With draft cattle a well-padded forehead yoke (Fig. 126) is used most frequently (for oxen), less often the neck yoke (Fig. 127), and only in isolated cases the collar yoke (for cows) (Fig. 128). All harnesses and appliances should, of course, fit well, which is generally most difficult to accomplish with the neck yokes. The double yokes are objectionable; double forehead yokes are an absolute cruelty to animals.

The *saddle* should rest upon the horse uniformly excepting along the mid-line and should fit the shape of the horse's back; only the withers should be free from pressure. A space of about 3 cm. (a little more than an inch) should remain between the withers and the saddle to prevent fistula and injuries from pressure on the withers. The saddle should fit snugly and should be belted on securely. Blankets placed underneath the saddle should not have wrinkles or folds; they should be even and smooth and likewise leave a space over the withers.

A well-fitting riding saddle consists of the wooden tree with saddle cushion and the carrying frame upon which the weight rests. The wooden frame rests upon very strong, soft pads. The straps for the two belly girths, the breastband and rear harness are fastened to the wooden frame.

After returning to the stable it is advisable to take off the saddle and harness immediately, and not, as was formerly recommended, leave them on the horse for another half hour. The sweat and dust should be wiped off with a damp cloth or sponge from the saddle and harness where they rested upon the horse, and from the animal also, and attention should be given to any injuries due to pressure. To guard against such injuries the saddle should fit properly, the folded saddle blanket should be washed frequently, brushed clean, and shaken out thoroughly every time before putting on. If the mane is too long it should be shortened at the base of the neck. The skin of the back can be strengthened by means of cold rubbing or brushing.

II. Milk Production

A large quantity of nutriment is taken from the milk animals by forced production of milk and by-products. Such animals should be sufficiently fed so that their nutrition (in organic and mineral substances) does not suffer through milk production). Furthermore, if the cows are gradually allowed to go dry 4 to 6 weeks before calving, too great debilitation is prevented. Allowing the cows to go dry is not only advisable for hygienic reasons but also for economic reasons, for it has been proved that milk cows that are milked up to the next calving time give less milk during the following period of lactation than such cows that have been allowed to go dry as directed. Finally, milk cows should be kept under other favorable hygienic conditions.

Among such conditions are stabling, ventilation, etc. (see chapter on "Stable"), and exercise in fresh, pure air (see "Pasture and Exercising Lot"). With regard to the latter point it should be mentioned that cows may be used for draft work of short duration but that in doing so all severe physical exertion should be avoided, as it affects the milk secretion. According to reports of the dairy association in Algaeu, such work, when done by cows that are accustomed to it, exerts but little influence upon the composition of the milk, while animals that have not been used to working show greater deflections.

The question that has been asked so often, whether milk production among breeds of cattle that give a large yield of milk has already reached the limit of what can be hygienically allowed or

Fig. 129.

whether it has already gone beyond it, can not be answered in general but only in individual cases. If the milk production of good milk cows is compared with that of milk sheep or goats, it appears that comparatively speaking the cows are not far behind the production of sheep and goats. While goats give 10 to 12 times and milk sheep even 14 times their body weight in milk during one lactation period, cows give only 4.5 to 8 times their weight. The fact is frequently quoted that there has been a decided increase (up to 80 per cent and over) in tuberculosis among cattle that have exceeded the limit of milk production hygienically allowed; however, such statements are not always fully justified. Not only the milk production as such, but especially the changed conditions of management necessary in the interest of milk production, must be considered as the chief conditions favoring the dissemination of tuberculosis. If such cattle were released from milk production and kept under the same

conditions for manure production only, tuberculosis would not be eradicated. Milk production has not a very close causal connection with tuberculosis. It can not be denied, on the other hand, that forced milk production weakens the body in general as well as renders it especially susceptible to tuberculosis.

Special attention should be given to the care of the skin (p. 170) of milk animals, which is very often sadly neglected in their case. Systematic care of the skin is also desirable for hygienic reasons. By far the great majority of udder diseases are caused by bacteria. The infection very frequently takes place from without through the teat canal.

Infection can be avoided through cleanliness of the udder and its surrounding parts (belly, inner surfaces of the shanks, tail), through clean hands of the person milking, and by means of clean litter. Systematic care of the skin of milk animals is also advised for economic reasons. The milk yield is increased (Backhaus) by a general and systematic treatment of the skin. Finally, such treatment is necessary for sanitary reasons. Clean milk is of course better suited for the use of persons and animals than milk polluted by cow manure and numerous harmful bacteria. Also from this point of view the greatest attention should be given to the care of the skin of the udder, the belly, the shanks, and tail.

The udder should be washed off before each milking; the least that should be done is to wipe it off with a dry, soft cloth and then wash it at least once a week with warm water and soap, followed by rinsing off the soap with water and then drying the udder carefully with a soft, clean cloth.

To prevent the tail from switching back and forth while the cow is being milked, the tail should be caught by a cord or strap and fastened to one of the hind legs (Fig. 129). Cows that kick while being milked can quickly be broken of this habit if a blanket strap is buckled around the body directly in front of the udder.

III. Wool Production

The first thing to guard against in the care of wool-bearing animals is that the wool production is not injured by diseases of the skin resulting from microorganisms (sheep pox), animal parasites (scab) or by unfavorable atmospheric conditions, as, for example, continued rains.

One of the worst enemies is the sheep louse (p. 251), which greatly impairs the appearance and durability of the downy wool fibers. Preventive measures against the lice should be taken at the proper time to prevent their gaining the upper hand. The best remedy is

a good dip[7]. The sheep should be thoroughly washed with it and the wool cleaned with the minutest care. The animals should furthermore be sufficiently fed and kept in the open a greater part of the time, especially since keeping them on pasture is more economical. Staying in the open also aids the growth of the wool, in so far as atmosphere changes excite skin activity.

In individual cases the wool is also injured by so-called "wool-eating"—the animals eating wool from each other—which now and then results from their being kept in the stables. This vice or disease, which can perhaps be traced partly to hunger for some particular nutritive substance (perhaps salt), but in which imitation also no doubt plays a certain part, can be best combated by putting the animals out to pasture. Wool-eating is also injurious to health, as the wool becomes matted into balls in the stomach, and these enter the intestines and may cause fatal obstructions.

Special care should be given to the washing and shearing of sheep. The shearing is done either twice a year, or three times in two years, or once a year. The first and second methods are practiced in the province of Saxony, occasionally in Pomerania and in Altmark. The wool is left on the animals 6 to 8 months and is then sheared while in its dirty condition. The method practiced most generally is shearing once a year when the wool is twelve months old ("full grown"). Shearing time is from December to June, the best time being in April and May. The sheep are usually sheared "in sweat" (dirty), seldom first subjected to a thorough washing with cold water. The latter should be undertaken only during the warmer months of May and June. It is advisable to sprinkle with water the passage along which the washed, wet animals are driven, as well as to renew frequently the litter in the stalls. The shearing is done with ordinary sheep shears or with a shearing machine which is driven by electricity or hand power. It is taken for granted that the skin should not be injured during the shearing. To prevent colds (catarrh of the respiratory channels, diarrhea, rheumatism) the temperature of the bath water should always be about 20° C. (68° F.) and the weather should be dry and warm. During dry, sunny weather the sheep should be left in the open during the daytime after the bathing but should not be exposed too much to the burning rays of the sun (erythema solare). At night and during cold, rainy weather they should be brought into the stables and provided with plenty of warm litter. They should be fed well during the first few

[7]As dips for destroying sheep lice the U. S. Department of Agriculture (Farmers' Bulletin 1150) recommends coal-tar, creosote, cresol, arsenical solution, and 0.07 per cent nicotin solution with 2 per cent flowers of sulphur. Many good commercial dips emboyding these substances are on the market. To eradicate lice it is usually necessary to dip at least twice, with an interval of 14 to 16 days between dippings. As a remedy for sheep scab (caused by the mite *Psoroptes communis ovis*) the Department officially recognizes lime-sulphur and nicotin-and-sulphur dips, though other dips may also be effective when properly used. To cure scab two dippings 10 to 14 days apart are necessary. For further information regarding sheep scab see Farmers' Bulletin 713.—J. R. M.

months after shearing, for the shearing has robbed the sheep of their most efficacious protection for warmth, and the heat production must therefore be accordingly increased to a considerable extent. The increased combustion of substances necessary for creating heat must be met by an increased consumption of food. With the object of providing the animals with warm quarters after shearing, stables have occasionally been tightly closed, all possible artificial and natural ventilation has been eliminated, and an attempt made to heat the stable with the decaying manure. This, instead of maintaining health, has caused many fatalities due to suffocation. The stable should be airy but free from drafts, as has been fully explained elsewhere.

During shearing there is always danger of injuring the sheep and thus causing diseases due to wound infection. These maladies can be prevented by washing with disinfectants (e. g., 2 per cent lysol solution).

Concerning "ovagsolan," which is recommended to further the growth of wool, see Klimmer, "The Scientific Feeding of Animals," 3d ed.

IV. Fattening

Feeding is the most important feature in the care of animals which are to be fattened; upon it the hopes for results are especially dependent. Therefore everything should be avoided that might harm the appetite or the digestion. With this in mind, stress is again laid upon the temperature in the stables. The amount of heat given off by fattened animals is substantially lessened by the deposit of fat in the subcutaneous connective tissue. Even in case of only a fairly high outside temperature, insufficient escape of body heat leads to heat congestion, which decreases the appetite and injures the fattening process. In case of high outside temperature the heat congestion may become dangerous and lead to heat-stroke, especially if physical exertion and excitement (transporting on hot summer days) are added.

V. Breeding

"There is no gain in attaining great services from our animals without lasting maintenance of their health, but rather it is a loss for which it is difficult to compensate." Thus writes F. Hoesch in his book that is well worth reading, "Pasturage in Hog Raising." This important principle is too often overlooked in animal husbandry. Health and a certain amount of power of resistance are requirements of progressively greater importance, the more the animals are removed from the natural conditions of sheltering, feeding and care which are essential to life. A marked degree of efficiency, "perfection," should be developed and continued for breeding purposes only

so long as the health of the animals does not suffer. "Overbreeding" and other extremes practiced in breeding should be avoided. The danger of overbreeding is present in too much inbreeding, for, under this practice, the future generations inherit not only the good qualities of the parents but also their weaknesses, which are easily and surely raised to a higher power in the descendants. Weakening the constitution by inbreeding also lowers the power of resistance against infectious diseases (tuberculosis, etc.). This and other facts about breeding have been experimentally confirmed by Duerst with guinea-pigs and rats.

In breeding the following distinctions are made:

1. Breeding from new outside blood, or outbreeding.
2. Breeding related animals, or inbreeding.

We refer to inbreeding when the same individual is represented once or more than once on both the sire and dam sides among the antecedents of one animal.

By relationship is meant when two animals descend from a common ancestor to the fifth or sixth generation.

In inbreeding we distinguish between (a) closest inbreeding, i. e., mating sisters and brothers, parents and children, or grandparents and grandchildren; (b) close inbreeding, i. e., the mating of cousins, or uncle and niece, or aunt and nephew; and (c) moderate inbreeding (line breeding), mating more distantly related individuals.

That inbreeding can be and has been employed in animal husbandry with the very best results can no longer be doubted. On the other hand we also know that the favorable effect of inbreeding may fail to appear and even great disadvantages and severe harm may result, as overbreeding, barrenness, lack of power of resistance, decreased efficiency, etc. The majority of these can undoubtedly be traced to careless or incorrect management of inbreeding, and the more reversionary the related parent animals are the more one-sided the breeding is. The more unfavorable the housing and conditions and care given, and the more intensive and more frequent the inbreeding, just so much greater are the disadvantages and damages.

Inbreeding is not suited to the majority of utility breeds where an exact knowledge of complete information about the pedigree (relationship), serviceability, physical characteristics, health, hereditary transmission, etc., is lacking. Inbreeding can be applied most usefully only in fancy breeding, with a known, definite aim in view, under the supervision of a capable individual breeder or superintendent. To avoid inbreeding new blood should be infused now and then.

The disadvantageous results of overbreeding for serviceability are most readily apparent in the hog industry. The breeding, which in this case is mostly directed toward increasing the fattening capacity, will, if carried to extremes, cause the fat not only to be deposited on those portions of the body where it is naturally de-

posited but also to be stored more or less in all organs and cells of organs. In this way the activity of the organs is greatly impaired and even stopped entirely. The heart and the respiratory muscles act inadequately and under anemic conditions favor diseased fatty degeneration. Young animals die at once from weakness or cramps, etc. Others contract infectious diseases due to a lowered power of resistance. With young pigs prolapsed rectum and umbilical hernia often occur, pointing toward an atony of the tissues.

Cows that give an excessively large yield of milk have not only a tender, fine skin but also tender, loose tissue. Such an extreme delicateness is accompanied by an increased susceptibility of the entire body. Such animals are more easily affected by disease infections such as tuberculosis, infectious abortion, etc.

In horse breeding the disadvantages show up when overbreeding for racing efficiency is practiced. Frequent results are narrow chest, long, thin legs with faulty position, nervousness and lessened sexual ability.

To prevent all these disadvantages of extreme breeding for efficiency it is advisable to omit especially an exaggerated one-sided breeding for service, to avoid inbreeding, and to follow methods of management under natural conditions that tend to harden the animal.

Since the parent animals not only transmit their special virtues (e. g., efficiency in milk production, fattening and racing qualities, etc.) to their posterity, but, as has just been emphasized, also certain defects (*hereditary defects*) or tendencies toward diseases, care should be exercised in mating the parents to see that they are not afflicted with such tendencies toward diseases that can be transmitted. These hereditary defects include roaring, heaves, "dummy" (chronic hydrocephalus), periodic ophthalmia[8], various diseases of bones, joints and tendon sheaths in horses (capped hock, bone spavin, ringbone, splints, galls); acute fatty degeneration of the entire body muscles of hogs; also epilepsy, scrotal and umbilical hernia, gray and black cataracts among all animals, as well as numerous infectious diseases such as tuberculosis and glanders. Defects in character and vices (vicious disposition), kicking, biting, stubbornness, hiccoughing, tongue sucking, etc.) also are apt to recur in the descendants. They are therefore included among hereditary defects. According to Von Oettingen, the transmission of hereditary defects results only in 5 per cent of cases.

With regard to the inheritance of noninfectious diseases, it is not a matter of direct inheritance of the particular disease, but only a faulty tendency (posture, imperfect joints) and a low power of resistance of the tissues, as a result of which the disease itself does not develop until later under unfavorable outside influences. For

[8]Dieckerhoff and von Oettingen declare themselves, no doubt correctly, against the transmission of spavin and periodic ophthalmia.

example, spavin is not transmitted directly, but only the tendency toward spavin, which develops into spavin only when the animals are used too soon and too severely, particularly upon the hard ground. Furthermore, only congenital characteristics are inheritable, not acquired ones, as, for instance, mutilations or spavin caused by a severe contusion, etc. One would think that hereditary defects when transmitted would follow Mendel's law in animals the same as in the human.

Infectious diseases can be inherited as such, as, for example, tuberculosis, even if this is seldom the case. Inborn or inherited diseases always originate from "placental transmission." It is also taken for granted that in the transmission of the tendency toward a disease the tendency occurs in the case of infectious diseases, *e. g.*, tuberculosis. As long as we are not dealing with particular anatomical anomalies the transmission of a tendency is not proved, nor has this theory been otherwise definitely supported. With regard to the anatomical anomalies (*e. g.*, a variation in the upper thoracic aperture in the human), it is very doubtful whether it is the cause, or, as Pattenger assumes, rather the result, of pulmonary tuberculosis.

Experience up to the present time has indicated that among cattle, which of course must be considered first with regard to tuberculosis, the tendency exists so generally and to such a degree that there is no need of the transmission of a special tendency toward disease. If tubercle bacilli gain entrance to cattle under conditions favorable for infection[9] (temporary fluctuatian of the tendency), tuberculosis will result, irrespectively of whether the parents of the particular animal have themselves suffered from tuberculosis or not.

The animals selected for breeding purposes must possess in general the qualities that are expected from the next generation and be free of defects which are not desired in the descendants, although certain defects of one parent animal can within certain limits be equalized by certain

[9]Tuberculosis does not always result every time that tubercle bacilli are taken up, favorable conditions being necessary at the time in order to result in infection. If, for example, tubercle bacilli are taken up with food (milk), the bacilli that by chance find their way into the interior of the mass of stomach and intestinal contents (chyme) and remain there pass through the digestive organs without harming the animal in question. If other tubercle bacilli in passing through the intestinal canal chance to reach the mucous membrane they still will not cause the disease; they must first be carried into the tissue. This can happen through phagocytes, which emerge to the surface of the mucous membrane, there absorb the tubercle bacilli and then wander back into the mucous membrane. The phagocytes finally succumb to the necrotic action exerted by tubercle bacilli. The latter multiply in the dead phagocytes, grow out, or are set free by the disintegration of the designated cell, and then produce a tuberculous process where they are located. This may occur in the mucous membrane of the intestine, in the regional mesenteric lymph glands, or in organs farther removed (e. g., the lung) whither the phagocyte had carried the tubercle bacilli. We can thus easily explain that not every ingestion of tubercle bacilli leads to tuberculosis due to feeding. The greater the numbers in which tubercle bacilli are ingested the more certain it is that infection will take place. The conditions upon which infection depends are of greater importance than the transmitted tendency in determining whether the infection remains. Analogous conditions apply to the other portals of entrance for infection, even though each organ exhibits its own peculiarities. The chance of infection can, furthermore, be substantially increased by an injury of the tissue, even by the slightest epithelial defect that in itself is very insignificant. This "locus minoris resistentiæ" produced in this manner is often speedily removed; it has, therefore, not only wide but also temporarily narrow limitations. In this connection we speak of temporary deviations of the tendency which are especially influenced by the resistance against the bacteria (see chapter **"The Science of Immunity").**

merits of the other parent. It is not possible from a hygienic standpoint to discuss here more fully these and other important questions of animal breeding.[10]

Animals kept for breeding purposes should be fed appropriately and should be given an abundance of unrestrained exercise, especially in fresh, pure air. Their *use for stud purposes* should be within certain limitations. Sexual overexertion lowers the power of resistance against infectious diseases (tuberculosis, etc.). With females kept for breeding purposes (cows and mares) the sexual wearing out is limited by the period of gestation.[11]

Sheep and goats are mated but once a year, although the length of their period of gestation would allow two lambings a year. Only sows are as a rule covered twice a year.

With stallions the stud period at breeding stations lasts from the beginning of February until the end of June. At the Prussian stud stations the one-year-old stallions are not allowed to cover oftener than twice a day excepting Sundays. The five-year-old stallions are allowed to cover only five times a week; 50 to 60 mares are allowed for one stallion. Privately owned stallions are usually required to cover many more (100 to 300 mares), which may, however, affect their capacity for service and fecundity as well as the quality of their offspring.

Bulls are often used for breeding purposes during the entire year. A full-grown bull may serve 100 to 120 cows; a bull one and a half to two years old about 75 cows, and at the age of one and a half years, 50 cows. If the covering takes place only during certain months the number of cows should be lessened from one-third to one-half. Bulls one and a half years old are allowed to cover once, at the most twice, a day; older ones two to four times.

Young rams and buck goats can cover 40 to 80 females, or 2 to 6 daily, during their short breeding period, which lasts but 4 to 6 weeks. Full grown rams and buck goats are allowed to cover 60 to 100 females, or 4 to 6 daily.

A boar may cover 20 to 30 sows, and if the breeding period is extended over the entire year 40 to 60 sows, service twice daily. In the case of rabbits, 10 to 15 females are allowed for one male. He is allowed to serve only every second or third day.

Animals should not be used too young for breeding purposes; stal-

[10]For further discussion of the principles of breeding see the following publications of the U. S. Department of Agriculture: Farmers' Bulletin 1167, "Essentials of Animal Breeding," and Department Bulletin 905, "Principles of Livestock Breeding."—J. R. M.

[11]The length of the period of gestation is as follows: For the mare 11 months (330-350 days). For the cow 9 months and 10 days (280-290 days). For the sheep and the goat, 5 months (144-158 and 154-158 days respectively).

The period of gestation with sows lasts 4 months (111 to 119 days). The first and most important sign of pregnancy is the omission of the next heat. The animals' behavior changes. They become more quiet, more sluggish, eat more, etc. From the middle of the gestation period an increase in the circumference of the belly appears. With the aid of the Abderhalden test, according to Richter and Schwarz, gestation can be determined with 50 per cent of the cows after the third month; after the fourth to the ninth month, 100 per cent. After the fourth month of gestation clinical examination also offers positive principles for determining whether or not gestation is under way.

lions not until they are 3 to 4 years old, mares 3 years, bulls not under one and a half years, cows not under one and a half to two years, rams not less than one to two and a half years, ewes not under 2, goats at 7 to 10 months, boars not under one year, sows at 8 to 10 or 12 months, male rabbits at 9 months to 1 year and the females at 7 to 8 months. The higher numbers apply to thoroughly purebred stock. Breeding at too early an age injures the parent animals and as a rule produces weak offspring. With stallions the capacity for sexual service gradually decreases after the twentieth year. Mares may also be bred to the twentieth year.

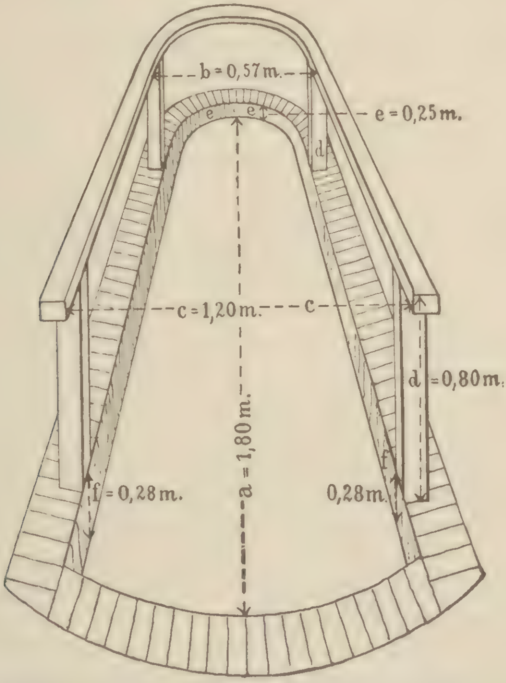


Fig. 130. Serving stall for cows. In Veterinary High School of Dresden. (After Puschi.)

To assure fertilization, mares and cows should be covered during the first heat after a birth, *i. e.*, generally on the ninth day with a mare.

During the act of covering, the animals that are brought together should be protected against injury. Their relative size and weight as well as the entire behavior of the male should be considered, since a heavy, clumsy male can crush a slight, weak female during service and thus injure her. However, such apprehensions are usually exaggerated. Only differences in breed and not in age are to be considerd with regard to the relative size of the two parent animals. This should be considered especially in connection with the birth which is to result. If mares are brought to stallions that are in the habit of biting mares in the mane, they should be protected against such injury by a cover or cape

that covers the skin and mane of the mare. The floor on which the stallion covers the mare should not be smooth or slippery, in order to prevent slipping if possible. The mare should be properly hobbled to avoid injury to the stallions. The tail of the mare should be wrapped or pulled aside with all the hair, so as to prevent injury to the genital organs from forcing the tail hairs in. If necessary the stallion keeper guides the penis into the vagina. The stallion should be trained to cover of his own accord. The room in which the copulation takes place should be quiet during coition. Frequently special breeding stalls are constructed, as shown in Fig. 130, for cows. With horses an ordinary box stall is often used. After coition the mare should be led about for a while, especially if there is a tendency toward straining. Mares that have been covered by stallions are again brought to the stallion after 5 to 7 days for a final trial. Cows should be covered only when they have thoroughly cleaned themselves and the discharge has entirely stopped. After coition the cow is often rubbed across the back with a stick; the slight pain thus caused prevents her from squeezing out the semen, a common vice among cows and heifers while in heat. Healthy cows that do not conceive should be fed sparingly. In this manner they may frequently be forced to conceive. However, some cows come in heat again in spite of having conceived.

Male breeding animals that are easily excited should be separated from the females if possible, except during the breeding period, in order that they may not be unnecessarily excited by rutting or heat odor and not become addicted to masturbation.

Stud animals should be well fed but not fattened. The feed should agree well with them. Meadow hay and a mixture of oats and chopped straw are well suited to stallions, bulls, rams and bucks. In addition to this the oat ration is increased or peas or beans are gradually added during the breeding period in order to increase the sexual instinct. Von Oettingen recommends the following feed for stallions during the stud period: 10 to 16 lbs. of oats in 4 rations, and 10 to 15 lbs. of meadow hay, 2 liters (quarts) of wheat bran moistened and mixed with the oats twice weekly. For the evening meal during one month in the early spring when the animals are shedding give daily 1 lb. of linseed meal (one handful to each of corn, oats, etc.). After the stud period in the summer 6 to 10 lbs. of oats besides freshly cut green feed (alfalfa, clover with timothy) should be fed. Young (halfblood) stallions which are trained further, receive an additional amount of oats and corn. (For further information see Klimmer, "Science and Study of Feeding.")

The male animals should be exercised in the open. Stallions should be exercised daily two and a half hours. They are frequently ridden. The other animals used for breeding are put out to pasture or at least in an exercising lot. Stallions and bulls may very well be used for draft work, which can be done without difficulty if begun early, and if done in moderation is very beneficial to the animals. The stable should be light

and airy. In order to manage the bulls more easily it is usually necessary to insert a nose ring provided with a head band. To prevent the spread of contagious diseases (contagious abortion, vesicular vaginitis) through copulation, the penis of the stallion and the bull should be thoroughly washed, using considerable force with a cotton pledget and a lukewarm, nonirritating disinfecting fluid, *e. g.*, one per cent chinosol solution, before and after coition. The animals should become accustomed to the treatment by exercising gentleness and caution. Simply rinsing the penis with an irrigator will not suffice.

The *pregnant females* should be fed nourishing food, but should not be fattened, as is fully explained in Klimmer's "Science and Study of Feeding." It has been found to be advisable, during the last few weeks before calving, in order to bring about a gradual drying of the udder and to avoid milk fever (parturient paresis), to feed the cows sparingly and by no means add to their feed. Well-nourished animals are even given purging salts. Daily exercise is very beneficial. Cows on pasture seldom suffer from milk fever. Immediately after calving care should be exercised not to overfeed. The feed should contain sufficient quantities of protein and especially phosphates of lime.

The use of pregnant mares for slow draft work should be done only up to the last 3 or 4 weeks before foaling. Cows may also be used for light work. During the last 3 or 4 weeks of gestation the work should be discontinued and free exercise in an inclosure should be substituted. Shoes should be removed from shod mares during the rather long time that they are not used for work. When pregnant animals are used for draft work they should not be driven at a too rapid gait, and should be prevented from hauling heavy loads, slipping, sinking into soft or thawed ground, as well as protected from blows of the wagon tongue and rough treatment.

All provocations that might lead to *abortion*, such as jolts, cold water, frozen, frosted, gas-producing or moldy feed and other harmful feeds, should be avoided as much as possible, as well as sudden changes in feed and extreme physical exertion. Abortion occurs especially with cows and can frequently be traced to an infection. Transmission not only takes place through the act of coition but also per os with contaminated feed and perhaps also from the outer genital parts.

It is urgently advised that in every case of abortion it be determined whether or not it is an infectious abortion, and if so, that measures be taken at once to prevent the disease from establishing itself in the stables. The economic importance of this disease is very great. The calf is born dead or dies shortly after birth; the milk yield will be far less during the following period of lactation than the usual yield; the afterbirth often does not come away and may lead to septic metritis, etc.

The surest diagnosis for infectious abortion is based on serological tests (agglutination, complement-fixation, precipitation) or specific local reactions (ophthalmic reaction). The following clinical symptoms should

be mentioned here: Swelling of the udder; colostrum-like nature of the milk; the discharge of a brown or reddish and slimy or dirty white pus-like exudate from the slightly swollen vulva. These symptoms usually appear 3 or 4 days before the abortion.

The following precautions for combating infections abortions are necessary: Immediate removal of the pregnant cow from the stable as soon as she shows symptoms of the approaching abortion, so that the infectious liquid will not be discharged in the stable. If the abortion has already taken place in the stable, the remaining pregnant animals should be removed from the stable. If this is impossible for economic reasons, then the cow which has aborted should be removed. If the calf survives it should be isolated. If the calf or fetus is dead, then it, as well as the afterbirth, should be buried or burned. The place upon which the abortion took place should be thoroughly disinfected (see "Disinfection" in the last chapter). The uterus of the cow should be flushed three times daily for 8 days with a warm one per cent solution of creolin, bacillol, parisol, or a five per cent solution of lysol. The cows infected with abortion disease secrete the abortion bacilli in the milk for years. It is therefore advisable to boil or pasteurize this milk before feeding it.

It is very advisable to use a special bull for covering the cows that have aborted. The bull undoubtedly often transmits the infectious matter. If for economic reasons it is impossible to take this precaution, then the penis and foreskin of the bulls in diseased herds should at least be disinfected with a two per cent lysol solution, etc., before and after each covering. The cows that have aborted should not be covered again until the discharge from the vagina has entirely stopped.

If infectious abortion has broken out in a stable the healthy cattle should undergo a specific vaccination for protection, the diseased ones for cure. Since retention of the afterbirth, imperfect conception and excessive and irregular œstral periods (bulling) depend on abortion infection, inoculation can also be recommended for these maladies whenever infectious abortion is the cause.

During the latter part of the gestation period an unusually severe swelling of the vagina, vulva, perineum, udder, abdomen, and lower part of the chest sometimes appear, especially among cows. To remove this trouble the animals should be led quietly about for 15 to 30 minutes several times a day. The muscular action promotes circulation and especially the return flow of the blood, and thus the swelling resulting from congestion is usually removed. If milk flows from the test channels several days before birth, which occasionally happens with good milk cows, the animal should be milked two to three times daily in order to relieve the tension. Milking out offers the cow considerable relief; she can lie down again and rest from the fatigue caused by her long standing. The milking out should be done only in case of necessity. Milking before parturition is not good for the calf, because the colostral milk thereby becomes unfavorably changed.

In order to prevent prolapse of the vagina and abortion, pregnant animals should not be given a stall that slopes too much. These ailments according to Johne, may also be caused by unaccustomed severe physical exertion (land or rail transportation).

Animals that before calving must remain lying down must be fed especially carefully with a laxative, easily digested feed that nourishes, is not bulky, and will not cause flatulency. At the same time an abundance of straw for bedding is given and leveled so that it is horizontal and the hind parts of the animal do not lie lower than the fore parts, so as to prevent prolapse of the vagina. If bloating happens to result from obstructed eructation, the cow should be placed on her right side or brought to an upright position on her knees and hocks; belching will result almost immediately and the bloat will disappear. Besides this, such animals as

Fig. 131. Contrivance for lifting a cow.

are forced to remain lying some 14 days before parturition should be rolled over on the opposite side twice daily in order to prevent bed sores. This should be done not by rolling over the back but over the legs that are bent under and against the body of the cow. It is also expedient for furthering the circulation to rub the legs and the body with bunches of straw, etc. The use of spiritous remedies (*e. g.*, spirits of camphor) is unnecessary for this purpose. It is taken for granted that any attempts made by the cow to get up should be assisted; it is often quite possible to get her on her legs again. Sometimes cows are prevented from getting up only because they are lying too near the crib or partitions. In such cases they can not stretch out the head and neck far enough in order to get to their knees. In such cases the animal should simply be pulled back. To help or raise a cow effectively in getting up, it is advisable to employ the method specified by Johne. A strong, long rope is tied taut,

lengthwise around the cow in such a way that it lies under the sternum in front and under the tuber ischii behind (Fig. 131). On each side three persons lift up the cow by the rope, first by the hind part and then by the fore part.

When *parturition time* approaches (indications are swelling of the udder, sinking in of the broad pelvic ligaments and flanks, discharge of a slimy fluid from the vulva, swelling of the vulva and appearance of labor pains) sufficient room and a soft bed should be provided. If the cow can lie down only with the greatest difficulty because of severe swelling of the udder, it should be milked out.

In case that considerable traction might be necessary for pulling out the calf, two men should be ready, two or three ropes should be boiled, two round sticks about 35 cm. (14 inches) long and 4 cm. (1½ inches) thick should be procured and lukewarm water, soap, several towels, 500 drams rape-seed oil or olive oil, a basin, nail brush and creolin or some other disinfectant should be provided. The mother animal should then be left to herself but should be carefully watched.

The expulsion of the young is accomplished by the labor pains (under normal conditions). Distinction is here made between (1) the preliminary or opening labor pains, which open the birth passages (neck of the uterus, etc.) without the co-operation of abdominal pressure, and (2) the expulsive labor pains, which begin with the so-called breaking of the water bag. When the neck of the uterus expands an important function is fulfilled by the water bag (the outside bag, which consists of the chorion and the allantois, appears bluish red and contains a cloudy fluid). The water bag should therefore not be ruptured until it has sufficiently opened the birth passages, which has happened when it can be felt between the lips of the vulva. It usually bursts of its own accord. If, however, the water bag has not yet burst when the forelegs of the young protrude as far as the knees and the head as far as the eyes, it should then be ruptured. It is followed by the amniotic bag (inside bag, shiny white in appearance; within this the head and feet of the young animal can be felt). The amniotic fluid performs the important function of lubricating the birth passages and thus makes them more easily passable. If the forelegs have protruded from the vulva as far as the knees and the head as far as the nose, the amniotic bag should be opened. The labor pains can then be assisted by exerting a quiet, even traction on the forelegs. The boiled ropes are fastened above the pastern joint, and at the other end are tied to the round stick, which serves as a handle. The pulling should be done in the direction of the pelvic floor. In the mare the broad, almost level pelvis slopes upward very slightly toward the back and has no raised side rims. In the cow the pelvis is narrow, bent up at the sides, and slopes upward at the back toward the tail. In the hog and the sheep it is broad, bent up at the sides, and, as in the goat and the dog, sloping slightly downward toward the tail.

Quiet and patience are the best helpers in assisting at birth. Patient waiting, within certain limits, is better than hasty, inconsiderate interference or even the assistance of insufficiently instructed persons. With the mare the preliminary or opening stage lasts about a half day, the explusive stage one-quarter to one-half hour; with the cow the opening stage up to 6 hours, expulsion 1 to 3 (to 6) hours; with sheep and goats, 3¾ hours and 1 hour respectively; with the sow both last 2 to 6 hours; with the dog and cat all together 3 to 6 (to 10) hours.

If the head of the calf is so large that there is danger of a tear of the perineum while it passes through the vulva the lips of the vulva should be pulled over the broad part of the head with bent fingers. With the mare the head of the foal is at the same time pressed slightly against the lower angle of the vulva. In case of difficult birth mares are kept standing or are led about (to equalize the severe labor pains) until the veterinarian arrives. The earliest help is necessary.

On the other hand, during normal births the animals are allowed to lie down quietly during the period of expulsion. With a normal breech presentation of the foal the inner bag is not opened until the hind legs protrude beyond the fetlock joint. After one has assured himself that the tail also lies in the birth passage, the birth is hastened by careful pulling so that the foal will not suffocate.

The umbilical cord of herbivorous animals usually tears of its own accord at birth. With swine and carnivorous animals it generally remains intact and must be separated artificially, bitten off by the mother animals, or, better still, cut through with a clean, preferably disinfected, knife or scissors.

After the birth the mother animal should be given a bed of clean, soft litter with her hindquarters not too low, so as to prevent a prolapse of the uterus. She should be rubbed off with bunches of straw and should be kept warm and protected from drafts. At first the feed should be easily digestible and not too abundant. Cows are generally given warm gruels of linseed, wheat or barley meal and moderate quantities of hay. Green feed and cold water should be avoided during the first day. The change back to the accustomed feed is made gradually.

The udder should be washed off with warm water and soap, dried well, and then milked out. The tail and hind legs should likewise be cleaned. The stall and gutter should be kept clean.

The passing of the afterbirth should be watched for. In mares it normally follows in most cases during the first half (to second) hour, in cows after 4 to 6 (8) hours, in sows usually directly after the birth, and in goats within 2 or 3 hours. A delay in the passing of the afterbirth from 1 to 2 days causes no harm if the uterus is properly douched out. A longer retention requires the treatment of a veterinarian, that is to say, artificial removal. Animals should be prevented from devouring the afterbirth. Mother sows are said to form the habit of eating their young in this way. A discharge usually flows from the genital passages after

parturition (lachia), lasting about 8 days. It is simply a natural cleansing process and requires no treatment. However, if it should continue longer, douches (irrigation) with 0.5 per cent warm creolin solution are necessary.

The newly born animal should be cleansed of the mucus in its mouth and nose as well as of the filthy, slimy, yellow mass, the vermix caseosa, that covers the entire body. This may be done by rubbing off with soft hay or straw or by letting the mother animal lick the young clean. To induce the mother animal to lick off her offspring, the calf is sometimes covered with bran; this practice may, however, be dispensed with. Sprinkling the calf with salt, which is occasionally done, is objectionable.

With regard to the nourishment of the newly born animal, Klimmer's "Science and Study of Feeding" may be followed. If the calf is born weak and with suppressed breathing, artificial respiration should be instituted. The calf is placed on its back. One person takes hold of the forelegs bent at the knees, spreads the legs apart, and then brings them together again and against the chest wall. At the same time another person should take hold with his thumb under the arched ribs and in harmony with the first person alternately expand and contract the thorax. Artificial respiration should, if necessary, be continued for half an hour or longer.

The umbilical cord is shortened, if necessary, to one hand's breadth. To avoid an infection of the navel it should be smeared with wood tar. Newly born animals should be provided with a warm, clean shelter free from drafts. In case the litter is too large, as is often the case with pigs, the mother animal can suckle only as many as she has teats. The remaining young pigs are either given to other mothers with fewer pigs soon after farrowing, or are frequently killed, as artificial rearing is too much trouble. Transferring the young pigs must be done soon, or the sow will not accept the strange pigs.

Among newly born calves that must be kept in the stable violent cases of *calf scour* very frequently appear during the first week of their existence. To overcome this severe malady the following measures are recommended:

1. The stall of the mother and of the two neighboring cows should be thoroughly cleaned before the birth occurs and be whitewashed with freshly slaked milk of lime.

2. The vulva and vagina of the mother cow should be douched with a lukewarm 3 per cent creolin solution or 0.5 per cent lysol, or bacillol solution, etc., shortly before parturition. The cow's tail should be tied to one side by means of a cord placed loosely around her neck.

3. The umbilical cord of the newly born calf should be tied near the body with a thread that has been boiled or been soaked in 3 per cent creolin solution, and should eventually be shortened and smeared with wood tar.

4. Immediately after the birth, before the cow has licked it, the newly born calf should be removed into a part of the stable that is fairly warm and free of drafts and that has previously been thoroughly cleaned and been whitewashed with freshly slaked milk of lime. It should then be freed of the mucus in its mouth and nose and rubbed off with soft straw or hay.

5. The calves should be given a dry, full bed of straw. Sick animals should be separated from healthy ones.

6. The udder of the mother cow should be wiped off before milking. The hands of the person milking should be washed clean.

7. The first strippings should be milked into a special receptacle and destroyed.

8. The calf should receive the milk warm from the cow, if possible from its own mother, out of a vessel that has previously been thoroughly cleaned or been scalded. Sometimes a muzzle made of closely woven willow is put on the calf during the first 8 days after birth and is taken off only during feeding times. During the first three days the calf is given only 1½ liters (quarts) of milk; after that ½ liter is added every second day until 9 or 10 liters are being fed.

If calf scour has broken out in a stable, the healthy calves should be separated from the sick ones. After the disease has been eradicated that part of the stable in which the sick calf stood should be disinfected (see "Disinfection" in the last chapter). As a preventive (and cure) of calf scour the calf-scour serum first prepared by Jensen has proved satisfactory. For several years the author has also obtained good results from "ventrase" (prepared by Humann Teisler, Dohna, Saxony), which is not injected but given with milk in the following manner:

1. The newly born calf receives its nourishment out of a pail that is kept clean, or, better still, has been scalded or boiled with a hot soda solution. As nourishment it receives the fresh milk with natural warmth (not boiled) from its own mother 3 to 5 times daily. A calf is easily taught to drink if at first the head is pressed down to the milk and a thoroughly clean finger is held out from the milk toward it. It will begin to suck at the finger and without further trouble soon learn to drink the milk.

2. To every liter of milk in the milk ration add one tablespoonful of "ventrase," which should be shaken well beforehand and mixed thoroughly with the milk.

Administering the remedy should be begun with the first milk ration and should not be delayed until calf scour breaks out.

VI. Rearing Young Animals

Young progeny when rationally reared require suitable nutrition and ample exercise in fresh air, which is afforded best through pasturage but in emergency on exercising lots. The first exercise in the open is given to calves and foals after 10 to 14 days. After 6 weeks they are allowed a quarter of an hour, gradually 1 hour, and finally 2 hours daily in any weather so that they will be prepared to stay out in pasture. As soon as the sexual instinct begins to develop, which usually occurs with horses and cattle at 5 to 9 months, with sheep at 5 to 6, with pigs at 2½ to 3 months, the sexes should be separated, to avoid the mutual development of detrimental sexual excitement or of a premature conception. If the young animals return from the fields wet from the rain they should be rubbed off.

The foals that are being weaned should be wiped off daily to remove the worst dirt and should be cleaned thoroughly every 4 or 5 days. At the same time the hoofs should be inspected about every three weeks and kept in order by cutting, trimming off and tarring. The frog is cut smooth and the lateral clefts of the frog are kept open. A contraction of the hoof should be corrected by trimming the bent-over buttresses with the hoof knife. Crooked hoofs should be straightened. With proper treatment of the hoofs incorrect postures of young animals can gradually be improved. A hoof that is worn off on one side more than on the

other can not be corrected by shoeing until after the sixth month, usually not until after the tenth.

Foals are usually weaned at 4½ to 5 months. As to other animals, see Klimmer's "Science and Study of Feeding." Since the act of weaning seriously affects the nutrition and disposition of the sucking foals, they should be stabled sufficiently so far away from the mother that they can neither see nor hear her, thereby allowing the development of the foals to progress uninterruptedly. They should be shut in their new stable at least 24 hours. A separation of the sexes should be made immediately at the time of weaning or a few weeks later. The weaned foals should be given a roomy, light stable with constantly fresh water and an adjoining good inclosed pasture. The larger the number of foals that are simultaneously weaned the sooner they become quiet. The sociable, companionable to exist soon causes them to forget the mother. If weak, underdeveloped foals are mistreated by their more robust comrades, they should at least be kept apart in the stables.

The care of the hoofs and the skin should be begun when young foals are 4 to 6 weeks old, especially when they are being reared in the stable.

Section VI

The Pasture and Exercising Lot

A. The Pasture

Pasturing farm animals is not only the most natural means of providing them with feed but also the healthiest and by far most economical. In breeding and rearing cattle free from tuberculosis, pasturing is indispensable; it also lowers the cost of rearing. Before the World War Falke estimated the cost of production of a 2½-year-old cow reared entirely in the stable at 440.80 marks ($104.91), but when pastured only at 315.10 marks ($75.00). With pasturage the 2½-year-old cow is therefore 125.70 marks ($29.90) cheaper than when reared in the stable, in addition to which we must consider that the pastured animal is much more efficient (has greater ability to work) than the stable animal. With the present high cost of things the cost of production has increased to such an extent as to make pasturing still more economical.

The beneficial influence of pasturing *on the animal organism* is very complex.

Through pasturing the organs of locomotion (muscles, tendons, ligaments and bones) are strengthened and hardened as a result of their constant use. Moderate physical exercise is the most important medium in the care of the locomotory organs. Exercise is essential for horses, particularly in the rearing of foals, so that the locomotory organs, upon which the entire value of the animal depends, can be strongly developed. On the other hand, the animals take up nutriments with the grass, clover, etc., particularly feeds that are rich in lime as well as in phosphoric acid (bone salts). The high content of these substances in the grass enables the young animals to obtain fully their great requirements of these and to develop strong bones. Likewise, older animals, that have become impoverished in salts as a result of unnatural methods of feeding, can again raise their salt content to normal. Pasturing acts not only as a preventive against bone diseases and softening and brittleness of the bones, but even as a cure for these ailments. Animals reared on pasture have a much better outward appearance than stable-kept animals. Physical defects such as a sunken back, "hay belly," narrow chest, weak hind quarters, saber legs and steep shoulders develop principally only in stable-reared animals.

The appetite is stimulated by physical exercise combined with fresh air as well as by palatable, succulent feed. The beneficial dietetic action of fresh green feed upon the digestive organs is a well-known fact. With

the proper selection of pasturage a sufficiently nutritious feed is made available to the animals which will improve the general state of nutrition and through the influence of exercise lead to a vigorous development of the musculature, *e. g.*, increase in flesh. The young, succulent meadow plants act very favorably on digestion and nutrition because of the aromatic substances they contain, their richness in easily digestible protein and amino substances, lime salts, etc. Feed raised in the fields does not have these advantages to the same degree. The property of stimulating digestion is especially peculiar to very young plants, as they constantly replace themselves so rapidly as almost to grow again under the very teeth of the animals.

Exercise causes an increased metabolism—an increased combustion of organic foodstuffs. The increased amount of carbonic acid that is formed and the increased consumption of oxygen by the tissues results in stronger heart activity and respiration. Through increased activity and a more copious supply of blood the heart muscle is strengthened. The lungs are more thoroughly aerated and thus their development and perfection are promoted. Pasturing furthers the development of breadth and depth of the thorax. During exercise the lungs are filled with air to the very apexes and edges, and the stagnant mucus in the bronchi and trachea, which is an excellent nutrient medium for pathogenic bacteria (especially the tubercle bacilli), and which favors the localization of these bacteria in the respiratory tract, is expelled, and in this way the contraction of an infection is rendered much more difficult. Outdoor atmosphere contains few bacteria and is free of disease germs, especially tubercle bacilli. On the other hand, stable air, which contains many bacteria, often contains disease germs (tuberculosis, swine plague, etc.), which gain a footing and produce diseases far more easily among animals that are kept in stables because of their superficial respiration and the stagnant mucus in the respiratory passages.

Pasturing animals also materially lessens the possibilities for contracting infectious as well as noninfectious diseases, *e. g.*, white scours of calves, contagious pneumonia of calves, infectious panaritium, parturient fever, sucking mania, bone brittleness, etc.

The changes of weather to which animals on pasture are more or less exposed exercises a strengthening influence on the organs which regulate the body heat, particularly upon the skin. In this way the animals become hardened; they develop the power of resistance against colds. Their skin accustoms itself to giving off heat according to the need of the body. To produce healthy and hardy animals, pasturing should be begun early in the year and continued as late as possible in the fall. The danger of colds is usually over-estimated. Even under the weakening influence of domestication not more than three per cent should be susceptible to colds.

Experience has furthermore taught us that male breeding animals kept on pasture can be used much longer for breeding purposes, and that the

females become pregnant to a greater extent. Furthermore, births are easier and the offspring inherits a higher degree of vitality.

Staying out in the open also exercises a beneficial influence upon the nervous system.

Pasturing furthermore increases the power of resistance against the various outside causes of disease, and favors recovery from many ailments, because of the varying influences of the sun, wind, rain, etc. Pasturing animals also has the power of equalizing to a considerable extent the disadvantages resulting from intensive, one-sided use, as well as from intensive breeding and early maturing, these consisting chiefly of a reduced power of resistance, sterility, lower vitality, etc.

Staying out in the open in cool, damp climates, such as predominate in Germany, produces not only a thickening of the skin and an increased growth of hair but the development of the subcutaneous connective tissue. The latter is the storehouse for fat. The cooler the surrounding atmosphere the more fat is deposited in the subcutaneous tissue for heat protection. A 2 millimeter layer of fat lowers the power of heat conduction of the skin about one-half to two-thirds during average temperature.

Connected with pasturing is an increased exposure to light which increases the number of red blood corpuscles, hemoglobin content and metabolism. Sunlight therefore increases vitality.

Pasturing is suited to herbivorous animals (horses, cattle, sheep and goats) as well as to hogs. If less use is being made of pasturing in Germany than is hygienically necessary, it is mainly because more animals are raised in many parts of the country than can be fed by the feed produced there. Furthermore, certain uses of the animal are made more difficult, are encroached upon and even made impossible by pasturing. It can be stated, however, that in general less use is made of pasturing than is possible and advisable for the health of the animals. Pastures which have lately been established for young stock in various industrial sections provide for the previously mentioned need of rational rearing, and it is hoped that this practice will become general. Pasturing swine is not only economically possible but even advantageous. It is particularly necessary for the maintenance and restoration of a hardy, healthy constitution, the power of resistance against swine epizootics, of fertility, etc. In districts where extensive pasturage is impossible the young and mother animals should be provided at least with several hours' pasturing daily; where not even this is possible arrangements should at least be made that the animals have an exercising lot in which they can move about daily for several hours in fresh, pure air.

Pastures may be considered in three general classes, viz.:

(*a*) Natural pastures (the better mountain and valley pastures; poor mountain pastures; heath and non-nourishing moorland meadows).

(*b*) Artificial pastures (forage, grass and clover fields). For sowing a permanent meadow the following mixture is recommended: Twenty-

one kilograms of oat-grass or French rye-grass (*Avena elatior*), 11.0 kilograms of meadow fescue grass (*Festuca elatoir*), 1.6 kilograms of rough meadow-grass (*Poa trivialis*), 2.4 kilograms of bluegrass (*Poa pratensis*), 0.6 kilogram of bent-grass or redtop (*Agrostis alba* or *A. bulgaris*) and 3.4 kilograms of timothy grass (*Phleum pratense*). In general, plants are preferred that can easily endure frequent injury (grazing off) to the parts that are above ground, that grow again quickly, that do not suffer particularly when animals trample them, that yield valuable, good and readily eaten food, that do not become woody early and develop hard fruiting stalks or blades, that shade the ground well and protect it from drying out, that are sufficiently hardy to stand

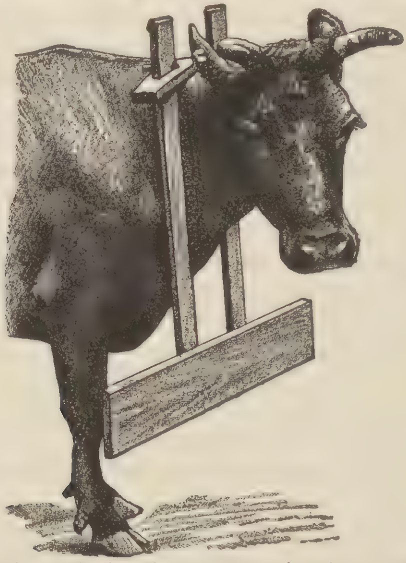


Fig. 132. Wooden neck piece for preventing jumping over ditches, etc.

the winter, that sprout early in the spring and continue to grow late into the autumn, and that are suited to the climatic and soil conditions.

(*c*) Additional pastures (untilled fields, stubble, old clover fields, meadows after harvesting the second crop, forest pastures).

Fences, etc.

For the purpose of inclosing pastures, ditches, fences, embankments or hedges may be used. Moats afford a safe inclosure if they are deep enough (0.8 to 1.3 meters) and wide enough (0.6 to 0.8 meter lower and 1.5 to 1.8 meters upper breadth) and contain enough water. The moats furthermore have the advantage of regulating the ground-water level of the pasture. After winter has expired weirs are placed in the moats until the water rises to within 30 centimeters (1 foot) of the upper level, then it is gradually lowered and kept at 70 to 90 centimeters (2⅓ to 3 feet) during the summer. It is customary to use moats as inclosures

in marshes. But they require much room and labor in order to keep them in good condition, otherwise they become marshy and grown over with plants. They offer a certain amount of danger to grazing animals, as, if the animals once get in, they can hardly work their way out of the bog again. Furthermore, swampy moats are breeding places for intestinal worms and other parasites. To prevent animals from jumping over the ditches and hedges a wooden frame is sometimes placed around the necks of cattle in northern Germany (Fig. 132).

Fences are usually the simplest and cheapest inclosure. They are sometimes made of wood in localities where wood is plentiful, but otherwise they are made of wire (smooth or barbed). Barbed-wire is said to cause many serious injuries. Fatalities may occur; slight cuts are frequent, but serious injuries, according to experience, seldom occur. Each animal must first make the unpleasant acquaintance of the wire. In order to avoid injuries as much as possible the upper wire is sometimes replaced by wood, or even a piece of lumber may be placed in the middle, or a ditch may be dug just inside the fence. In general the danger of serious injury from barbed wire depends on the liveliness of the grazing animals. Young foals are particularly endangered by it. Barbed wire is most dangerous when ends become loose and the animals get their legs caught in it. It is most essential that every wire fence, especially the barbed wire, be built very carefully and kept in good repair.

Barbed wire has the advantage of staying taut a long time; smooth wire soon goes slack. Barbed wire also keeps animals away from the fence. The animals do not attempt to climb through nor to rub against the posts. Barbed wire also keeps people away from the pasture.

Barbed wire fences are usually built as follows: Every ten meters (yards) a heavy post or reinforced concrete post is set in the ground to a depth of 60 centimeters (2 feet), standing 125 centimeters (about 4 feet) above the ground. At the top a smooth wire is fastened and in the middle, 22 centimeters (8¾ inches) apart, two well-galvanized, four-pronged, closely set barbed wires (not serrated) are stretched. Every two steps a pole, the thickness of an arm, is inserted between the strands and allowed to rest upon the ground so as to hold up the wire. The lower part of the wooden posts, as far as they are driven into the ground are preserved with hot tar, carbolineum, anthracite oil, 2 percent solution of copper or iron vitriol, creosote, or by partially charring. When pasturing young stock the lowest wire, if smooth, is fastened not more than 25 centimeters (10 inches) above the ground and the others the same distance apart. For milk cattle and foals three smooth wires suffice, but for horses it is advisable to add another row of poles.

For foals at least the lower wire should not be barbed, as the animals may easily injure themselves on the lowest wire by pawing over it with their forefeet. To fence in a hog inclosure the wires are stretched 15, 30, 45 and 60 or 70 centimeters (6, 12, 18 and 24 or 28 inches) above the ground. The two lower ones should be smooth, the upper ones

barbed. Where wood is plentiful poles are often used. For pigs and shoats a wire netting about 2.20 meters (2¼ yards) wide is fastened below. Various changes can be made in fencing, depending on the purpose and local conditions. If the barbed wire is omitted, the posts and poles must be stronger and stand closer together, as animals often rub against them. The fences of exercising lots (paddocks) must be especially strong, as animals often attempt to break them down from sheer tedium.

Earth embankments are frequently used in Holstein. They are durable, cheap and safe when combined with barbed wire without affording occasion for injury. If in addition they are planted they provide shelter against drying winds and give shade and favor the growth of valuable

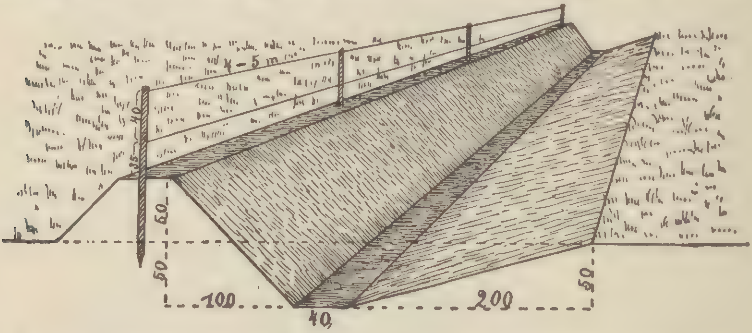


Fig. 133. Enclosure with lower fence, flat ditch and embankment (single ditch).

moisture-loving grasses. The inclosure is constructed as a single or double embankment. With the single embankment, which serves especially as an outer fence, a ditch 50 centimeters (20 inches) deep and 40

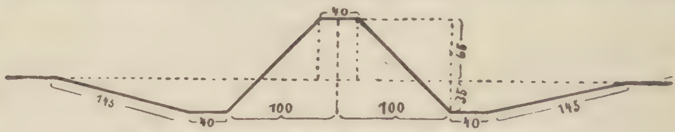


Fig. 134. Double ditch. Schematic representation.

centimeters (16 inches) wide at the bottom is dug and the soil thrown up to form a bank 100 centimeters (over 3 feet) high beyond and opposite the bottom of the ditch. The slope of the bank should be kept steep, while the other side of the ditch should slope gradually. The slopes should be sown to grass. On the top of the embankment, which should be 40 centimeters (16 inches) in width, a light fence 70 centimeters (28 inches) high is erected; every 4 or 5 meters (yards) a stake is placed and two barbed wires are stretched 35 and 70 centimeters (14 and 28 inches) above the top of the embankment (Fig. 133).

On each side of the double embankment which should be about 1 meter in height, and which serves first of all as a dividing boundary, ditches 35 centimeters (14 inches) in depth are dug out on both sides.

The embankments should be planted with hedges (hornbeam, hawthorn, hazelnut or elder) and at intervals also with chestnut trees, lime trees, oaks, pines, etc. The planting of the hedges offers welcome nesting places to a large number of useful birds. They also exclude an open view of the surrounding country and thus greatly overcome the desire of pasturing animals to break out.

The gates of the inclosure should be 2⅓ to 3 meters in width. The majority of animals are permitted to run about free on the pasture, which is of course to be recommended hygienically. Cattle are sometimes staked out with ropes when pasturing on clover, or are hobbled with a rope fastened to the head and tied short to one of the forelegs below the knee (shinbone), or have blocks of iron tied to their hind fetlocks, or a wooden frame placed about their necks, to prevent them from jumping over ditches or hedges. This wooden frame is flat and four-cornered, of such length that the lower, wide crosspiece hangs slightly above the height of the carpus (knee) when the neck of the animal is stretched out (Fig. 132).

Staking or Picketing Animals

Staking or picketing is practiced in Denmark and has from there been generally introduced into East Holstein. Occasionally it is also practiced in other localities. (In the United States this is commonly practiced.—Translator.) The staking is done in the following manner: A rope or light chain of about 4 meters in length is fastened to the horns, to the chain around the neck or to a halter-like head-piece; the other end is fastened to a wooden peg 30 centimeters long, that has been driven into the ground. The animals are usually changed to a different place six times a day. This should not be done in a straight line but in a zigzag line.

Staking offers the following advantages:

1. Economy of food. The pasture is eaten off uniformly and the feed trampled down less. Grass that has been cut grows better after a rest of several weeks. Red clover and the short-lived grasses withstand picketing better than allowing animals to graze promiscuously.
2. Increase in the production of milk because of less exercise.
3. Uniform scattering of manure.
4. Obviating necessity for fencing the pasture.

Staking has also its disadvantages, viz.:

1. Dependence on a personnel that understands staking or picketing.
2. Restriction of exercise and the resulting disadvantages.
3. Difficulty of watering the animals.

In extensive agricultural sections with large pasture areas, fencing pastures is often disregarded, the animals being prevented from straying away by hobbling. With horses both forelegs are often tied loosely together close above or below the fetlock joint so that they can take only short steps. With cattle the head is tied loosely to one foreleg.

This practice is especially objectionable because the animals hobbled in this manner can not protect themselves against flies.

Equipment, Shelter, Etc.

Scraping Stakes and Rubbing Posts.—Animals on pasture are usually not groomed; therefore opportunity must be afforded them to free themselves of dirt and vermin and to relieve itching. If trees and posts of the inclosure can not be used for this purpose, rubbing posts and scraping stakes must be erected on the pasture. Rubbing posts should be 1 to 1.50 meters high, erected 2 or 3 meters apart and connected by a sloping crossbeam (Fig. 166). For hogs the height should measure 0.3 meters to 1 meter and the distance between the stakes 1.5 to 2 meters. Simply a slightly bent scraping stake is often erected.

In order that the animals may brush off flies in case there are no bushes, the rubbing posts are erected one-half meter higher than above designated, and brushwood, which acts like a brush, is fastened so that it hangs down from the crossbeam.

Protective sheds and shelters do not serve against rain, wind and cold. Grazing animals soon become hardened to these. Animals that are on

Fig. 135. Shade shelter.

pasture should have become resistant to outside influences. All weakening influences are therefore kept from them. If animals are hardened systematically from youth the first generation may apparently be somewhat unfavorably affected thereby, but all the following generations will stand the test just so much better according to the intensity of the hardening influence on the animals. Hedges, embankments and knolls offer adequate protection against cold winds, and a well-nourished condition and plenty of food serve against cold weather. The main purpose of the protective huts lies rather in the opposite direction, that is, to offer the animals a certain amount of protection from the heat and intense light of the sun and from the tormenting of insects, hence, during the heat of the day, and not, as often happens, unnecessarily and sometimes even in a way that is injurious to health, during the night.

It is advisable to erect these shelters for protection on an airy eminence; here a cooling breeze blows which insects avoid. The cheapest and best protection is offered by large shade trees (maple, lime tree, chestnut tree, etc.) and by smaller bushes in which the animals can more easily defend themselves against flies. Young trees should be protected

against injury. If a shelter is erected for protection it is cheapest and best to build merely a roof for shade (Fig. 135) and most practicably on the boundary of several inclosures. For every head of full grown cattle 3½ to 4½ square meters of ground surface should be allowed; for young stock 1½ to 2½ square meters. The height of the roof should not be too great. Straw roofs have the advantage of cheapness and splendid protection against the heat, which roofs made of roofing paper lack. Walls should be entirely omitted or built only on the weather side and consist of rough boards painted with carbolineum or anthracene oil, or should be made of interwoven brushwood. If these shelters are also used as milking sheds a generous supply of litter should be put in, or a firm subsoil of cinders 8 to 10 centimeters (3 or 4 inches) deep, a layer of stones with a top layer of gravel as used in building roads or pavements. If the cows are tied during milking a rope 85 centimeters (nearly 3 feet) long is looped over their horns. The free end of the rope with ends in a thick knot is allowed to hang down 20 to 25 centimeters (8 or

Fig. 136. Summer stable for horses on pasture.

10 inches) on the forehead. In tying the animals the knot is put through a ring which terminates on one side in a slit 6 to 8 centimeters (2½ or 3 inches) in length.

Kinds of Pastures and Methods of Pasturing

Pasture for horses should be situated in a sheltered locality, should have abundant grass, and should be fairly dry, firm, and rich in lime, which exercises a beneficial influence upon the development of the hoofs, joints and posture. Damp, swampy ground, on the other hand, favors the development of a clumsy, bear-like posture and the formation of flat hoofs with their many resulting conditions.

For *cattle*, damp, shady pastures with a rank growth of grass are most suitable, while *sheep* prefer meadows that are drier, with thick, short grass, including species of *Poa* and *Festuca, Phleum pratense, Aira*

flexuosa and other grasses which are mixed with *Medicago, Trifolium repens, Achillea millefolium,* etc. Only marsh sheep require succulent, nourishing rank-growing grasses.

Hogs are pastured on fields of red clover without a mixture of grass and coriander. Hogs will not touch yellow clover. Alfalfa is also not suitable, because the stalks soon become woody. Hogs are also turned into fields of comfrey, "Topinambur" and maize (in Hungary), and into swampy, wooded meadows, particularly into woods of oak and beech. To prevent them from rooting a ring should be put through the nose. Sucking sows are best not driven to pasture, but should be allowed to stay near the pens with their young, where they may exercise. Not until after the young pigs have been weaned and the sow has again been covered is she put out to pasture. The young pigs are allowed to go along to pasture 10 to 14 days after weaning. But to make them thrive well it is advisable, as long as they are growing considerably, to give them an extra feeding consisting of skimmed milk or whey, boiled potatoes, table refuse, etc. Pasturing is also suited to hogs that are to be fattened later. Hogs raised on pasture gain more in weight when they are fattened in pens than hogs that have been reared in sties. If the hogs are full-grown the clover field suffices. Pasturing is the cheapest and most healthful method of keeping hogs. If hogs are pastured only 1 or 2 hours it is not necessary to provide water and a place to wallow; but if they stay out during the noonday heat they need water and shade.

Turning hogs out on forest pastures, when other opportunity to wallow (manure heaps) is afforded, may begin with the first nice spring days. Hogs should gradually accustom themselves to green feed. In case the clover pastures are located some distance away have grassy lanes leading to them, the hogs are first allowed to graze along the way for an hour each day. Hogs like to eat tender grass. Clover pastures are put to use when the young clover is 10 centimeters (4 inches) high. At first the hogs are allowed to pasture daily one hour; after three or four days, one hour twice daily. An acre of well-grown red clover pasture will completely provide for seven or eight full-grown hogs. Before driving the hogs to pasture they should be given plenty to drink and first allowed an hour on the manure heaps. Hogs do not soil their pens if they can avoid it. They should be driven out and pastured quietly. "Quiet and rest are half the fattening." In order to take good care of the pastures the hogs should not be allowed on them longer than necessary; otherwise they will begin to root for lack of something to do, trample down the pasture during wet weather and spoil it. When the hogs return they should be allowed to rest in the shade before being watered.

When stubble pastures are available the change from the clover pasture to the stubble pasture is made gradually. In the same manner the change to pasturing on potato and turnip fields should be a gradual one.

Purebred hogs are not well suited to pasturing in the woods; on the other hand the common grade hogs are well adapted to it.

The most recent efforts in hog raising to keep all breeding animals in the open day and night, summer and winter, and to bring them into the pens only during suckling time, have proved successful (Falke). As a protection against inclement weather shelters are erected. These shelters have a round or usually square foundation. On three sides a double wall of boards is erected. The intervening space of 50-70 centimeters (20-28 inches) is filled with straw, leaves, etc. The front remains open. The front side should be about 110 centimeters (43 inches) high, the back wall 65-75 centimeters (26-30 inches). Upon this the roof is placed; it is built of beams and poles upon which twigs and brushwood are laid, and upon these straw, potato tops and rushes. The layers are put on in this order to such a thickness that no rain can penetrate but that it will all drain off on the outside. A dry shelter is always kept clean by swine. They deposit the urine and dung outside. The roof should be supported by numerous strong posts that at the same time serve as rubbing stakes. A mother animal requires one square meter of ground area.

If the hogs stay in the open during the winter provision must also be made for a covered feeding place. An exercising lot with a solid floor of gravel, cinders, etc., to a depth of 10-15 centimeters (4-6 inches) is then often provided them. An area of 4-6 square meters is figured for one mother animal.

Two feedings a day are given during the winter. Pregnant sows receive per day 12-15 kilograms (26-33 pounds) of whole turnips and one-fourth to one-half kilogram (one-half to one pound) of grain with some chopped clover or chaff. The shoats receive to every 100 kilograms of live weight 5-7 kilograms of potatoes or 10-15 kilograms of whole yellow turnips, 1-2 kilograms of grain, with 100-200 grams of tankage, fish meal or blood meal, besides chopped clover and chaff. The pigs that have just been weaned (during the first month after weaning) are given, per 100 kilograms of live weight, 3-4 kilograms of potatoes or 6-8 kilograms of yellow turnips, 3-4 kilograms of grain not too rich in protein; during the second month 4-6 kilograms of potatoes or 8-12 kilograms of yellow turnips, 2.5-3 kilograms of grain not too high in protein content. During the time that pregnant sows, and also shoats that are over 4 months old, are on pasture they receive no additional feeding. The pigs that have been weaned receive 60-70 per cent of their winter feed ration in addition to the pasture grass. Sows that are still carrying their young are brought into the stables 10 to 14 days before the farrowing so that they may become accustomed to stable feed. The change in feed must be made before parturition.

The wallowing place should afford the hogs opportunity for bathing. If there is no natural bathing place one should be constructed of concrete, with a flat rim, in the vicinity of a spring.

Opinions differ as to the type of pasture for hogs. While Hoesch favors red-clover pasturage, Falke prefers the permanent pasture, that is, chiefly the grass pasture. The latter simplifies the management. A location and arrangement which is once correct (shelter, fencing, rubbing posts, watering place, wallow) will last for decades. Hogs do not have to be driven to pasture and watched. Rooting is prevented by placing rings in the hogs' noses. Red-clover pasturage nourishes hogs more intensively. Here the hogs can satisfy their desire to root and eat earth, gravel, etc., which aids digestion. It appears that in modern times permanent pastures are being given the preference.

The best pastures should be reserved for the young, ailing and convalescent animals, which are in special need of nourishing feed. Separation of the sexes is advisable as soon as the sex instinct is aroused. Whenever possible pastures not too far distant from the stables should be chosen if the animals do not remain out over night. This applies especially to young, weak animals and to milk cows whose milk yield is easily lessened by walking long distances. Sheep should not be driven along very dusty roads that can give rise to diseases resulting from inhalation of dust.

Pasture Capacity

The amount of pasture area to be allotted varies a great deal. It depends among other things upon the species of plants, the weather, soil, condition and the care of the pasture. Although one hectare (2.45 acres) of best pasture on river bottom lands can nourish three cows (over 1,500 kilograms or 3,300 pounds combined live weight) during the grazing season, the feed from the same area of poor soil will nourish only 0.6 to 1 cow. The mistake is usually made that pastures are overstocked. In that case the pastures are eaten off too closely and the plants are injured; and on the other hand the animals go hungry and their nutritive condition declines.

The following compilation affords a comparative survey of the utilization of 1 hectare of pasture area, first, by means of grazing cattle (cows about 500 kilograms live weight, grazing period 160-180 days), and secondly, by means of the amount of hay obtainable:

Quality of the pasture	1 hectare (2.45 acres) feeds cows	1 cow requires hectare	Yield of hay in double cwt.
Exceedingly rich or lowland pastures	2.3-2.9	0.43-0.34	50.70
Very good cow pastures or medium rich	1.6-2.3	0.62-0.43	40.50
Good cow pastures	1.3-1.6	0.77-0.62	30-40
Poor cow pastures	1.0-1.3	1.00-0.77	25-30
Very poor cow pastures	0.6-1.0	1.67-1.00	15-25
	Sheep	1 sheep	
Good sheep pasture	10-14	0.10-0.07	25-30
Medium good sheep pasture	6.2-10	0.16-0.10	15-25
Fair sheep pasture	2.9-5.8	0.34-0.17	7-14
Poor sheep pasture	1.2-2.5	0.83-0.40	3-6

Besides this a not insignificant additional profit can be made on well-cared-for pastures by planting timber and fruit trees. The fruit trees should be planted 12.5 to 15 meters from one another in rows 20 to 30 meters apart. The rows should run from north to south to receive as much light as possible. The crowns should be kept open and the trunks protected from attacks by grazing animals. As an additional utilization of the pastures Falke recommends keeping bees and poultry. The chickens eat up quantities of insects, worms and larvæ and also remove the intermediate hosts of dangerous animal parasites. They should be housed in portable pens whose locations are changed with every change of field.

By means of systematic pasturing, by suitable choice of plants when establishing the pastures, and with proper care of the pastures, sufficient feed is made available for the animals on pastures even during dry seasons when plant growth is diminished. In an emergency additional feed must be given them in the stables. To assure a satisfactory utilization of the pasture land it should be subdivided so that the supply of grass in each inclosure will last for about 10 to 20 days. The subsequent growing of grass lasts 3 to 7 weeks; during this time the fields should remain idle. A good utilization of the pasture is aided by allowing different kinds of animals to graze on the land; therefore besides cattle several horses are kept if possible, and also several pigs and sheep, *e. g.*, 4 cows, 4 sheep and 1 horse. The food that one kind of animals refuses the other accepts.

Care and Management of Pastures

With regard to the care of the pasture the following must be considered: Drainage of swampy areas, by means of which the growth of suitable plants rich in nutrients is favored; during droughts the watering of fields that have been grazed over; the watering should be repeated some time before using the fields again, so that the ground will have time to dry out and become firmer; also harrowing and rolling the pasture land in the early spring; sowing grass seed on bare places; leveling down the mole hills; scattering the manure piles; fertilizing (caustic lime, cheap carbonate of lime, marble dust or a high percentage of marl, 20 deka zentners (1,000 lbs.) to hectare (2½ acres) every three years—also of great importance for the animals; mowing down old woody plants; extermination of poisonous plants and weeds. Chervil (*Chærophyllum*) acanthus and thistles can be exterminated by allowing sheep that like to eat the young leaves to graze on the pasture 2 or 3 years. In this way nettles can also be exterminated. They may also be exterminated, the same as rushes, if they are mown down close and sprinkled with a 20 per cent solution of kainite or rock-salt solution. The swamp horsetails must be dug out and be eradicated through soil drainage. Some plants such as cockle-bur (*Xanthium spinosum*), stick-seeds (*Echinospermum* s. *Lappula lappula* and *L. deflexum* or *deflexa*), round-leaved galium (*Galium rotundifolium*), feathery and hairlike feather-grass (*Stipa*

pennata and *S. capillata*) and many species of the *Medicago* genus, all have seeds that are provided with barbed hooks (Figs. 137-140) and consequently become fastened very easily in the fleece of the sheep (so-called wool or hair lice) and can be removed only with difficulty. This causes the wool to depreciate in value very much. These plants should be exterminated on sheep pastures.

The time to begin pasturing depends upon the growth of the plants. Grazing may be begun as soon as the forage plants have developed sufficiently in the spring, and may be continued as long as animals can find

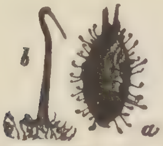


Fig. 137. Cockle bur (*Xanthium spinasum L.*). *a*, Seed; *b*, thorn with hook.

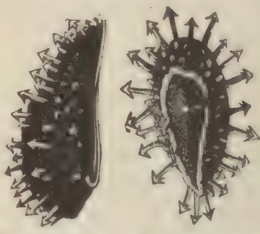


Fig. 138. *Lappula* s. *Echinospermum lappula*. *a*, Profile; *b*, back (x 10).

Fig. 139. *Lappula deflexa* Wahlbg. *a*, Natural size; *b*, enlarged; *c*, individual enlarged thorn.

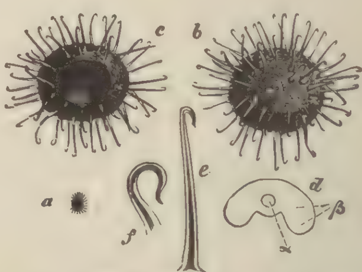


Fig. 140. Round-leafed Galium (*Galium rotundifolium*). *a*, Fruit in natural size; *b*, enlarged; *c*, belly side; *e* and *f*, enlarged hooks.

sufficient nourishment in the open. The time of pasturing is usually restricted from the latter part of April or beginning of May to the middle or even end of November. Early grazing favors the subsequent growth of the plants; the growth is denser, tenderer and of longer duration. In districts where extensive pasturing is carried on the animals not only remain on the pastures during the summer but also late into the fall and also at night. Keeping animals out overnight is a good way to harden them. According to Schneider, the milk production is two-thirds to three-quarters of a liter higher per day per cow if the cows also stay out on the pasture overnight. Animals that have not been sufficiently accustomed to pasturing should not be put out until after the mists have risen and the dew and hoar-frost have disappeared; also not until after having received a dry feed in the stable. Driving the animals out and back home should be done at a gentle pace.

Winter pasturing.—In more recent times attempts have been made to let the animals graze out during the winter. Since 1914 Kordel has

Fig. 141. Foals on winter pasture. (From Deutsche Landw. Tierzucht.)

carried on his experiments in the neighborhood of Bingen. The additional feed as well as the gain in weight were very slight during the

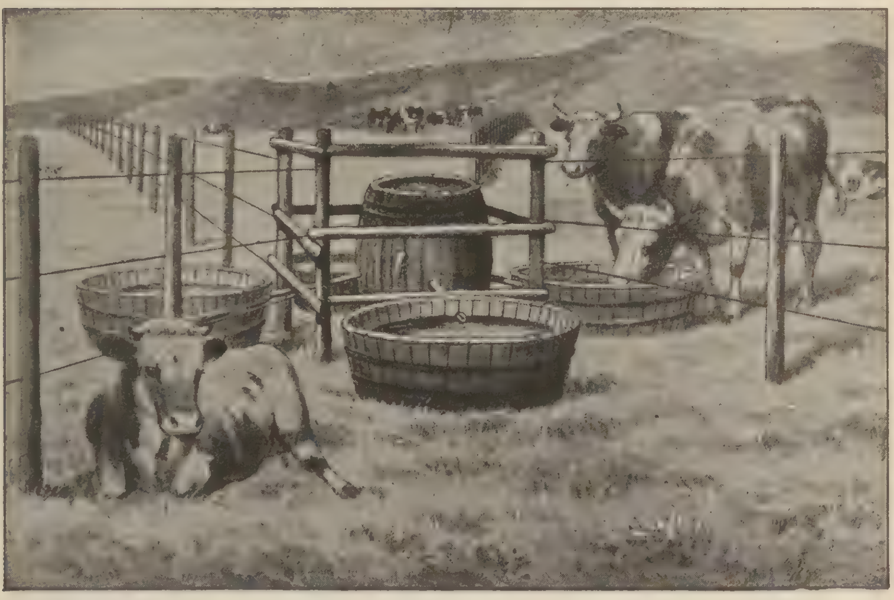


Fig. 142. Automatic drinking device for several pastures.

winter. Animals that had remained on pastures throughout the winter improved at once with the coming new growth of grass, while the animals that had been stabled during the winter were retarded in their development or even retrograded during the first few weeks of pasturing. The pastures should be liberally fertilized with Thomas meal (ground basic slag), kainite and lime.

One and two year old cattle are best suited for winter pasturing. They must have been able to nourish themselves from the pastures alone during the last summer and autumn and must be in a good general condition. During unfavorable winter weather additional feed should be given as required. Sufficient acreage of well-cared-for pasture must be available for the animals. Zorn has made similar satisfactory observations in Bavaria with well sown, dry and adequately fertilized pastures. The animals must first be reared for winter pasturing, and the winter stables must be suitable for the rough life on the winter pastures.

Wilke and Von Dungern also recommend winter pasture for foals. Wilke was able to conduct winter pasturing satisfactorily in a very rough, snowy, mountainous section of Germany (700 meters, Knuell mountains). The sheds that were erected on the pasture were not even used by the foals. They preferred to lie down in the snow that was one meter deep. They also did not care for the additional feeding. Hay and straw need be given only when the snow is covered with a thick crust of ice. However, a plentiful supply of fall grass should be available on the pasture. It is of advantage if the animals can be offered protection by woods and hills. The horses developed well. No losses occurred.

Von Dungern also gives horses on winter pasture only chopped hay and straw for extra feed. Only the stud stallion is fed 5 pounds of oats as long as the pasture is not in its prime. "During winter the digestive organs must be trained to be able to utilize everything from the moderate supply of feed. These lean spring animals are then very fat in June; the animals that received grains as feed are lean." If later on the hardened horses are given oats when they are put to work they extract a surprisingly large amount of strength from this feed with their "trained" digestive apparatus, as the "Panje horses" are well known to do.

Von Dungern recommends that if winter pasturing can not be continued throughout the winter the pasturing be begun as early as possible even if the pasture is still gray. The animals gradually become hardened and accustomed to the green feed, to which all the other regular feed is at first added. The Brandenburg Board of Agriculture also recommends that the pasturing of young horses and cattle be extended into the winter. Several well-known farmers also advocate winter pasturing.

I am convinced that the fight against devastating tuberculosis will be effectively aided by the natural pasturing of young stock in the open during the entire year, which not only hardens the animals but protects against the transmission of tuberculosis. In this way cattle not only

attain a natural power of resistance against tuberculosis infection but primarily can be kept free from tuberculosis until about the third year, whereas stable-reared animals have by that time already fallen prey in considerable numbers to tuberculosis infection. According to Schneider, reports of the practical use of this method have been made.

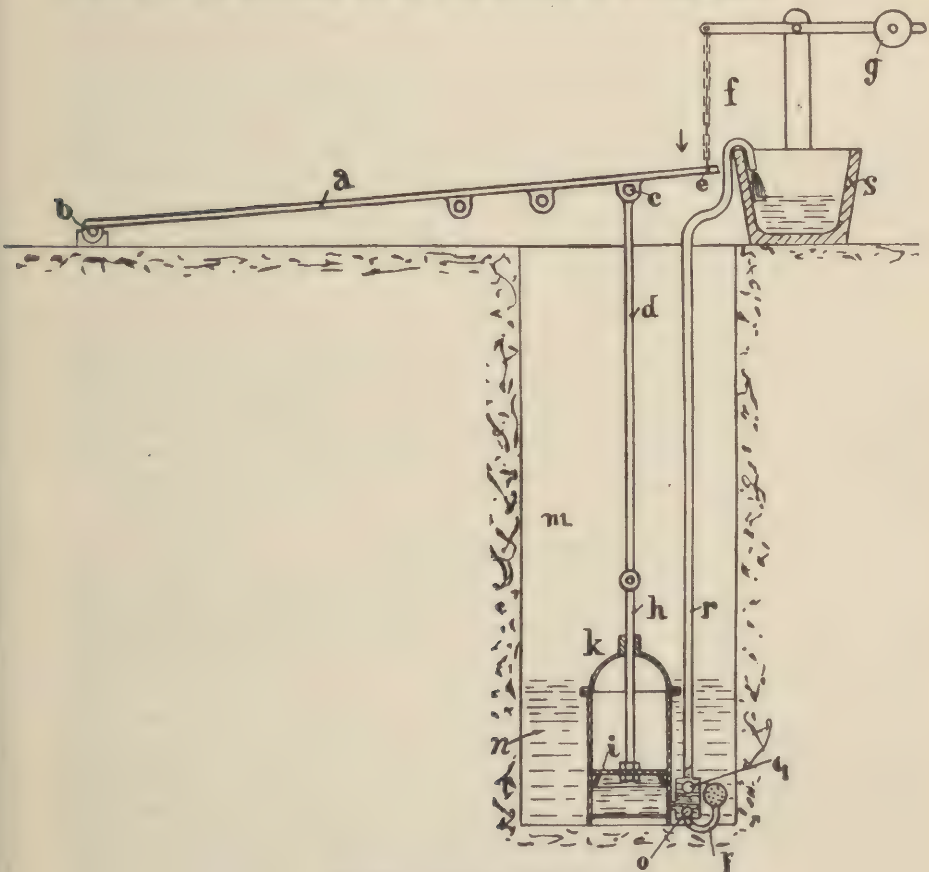


Fig. 143. Automatic well for pastures.

Watering Facilities

If animals stay on the pasture day and night, facilities for drinking must be provided (Fig. 42). If this is not done the animals' health and the milk yield will suffer; the animals also become very restless and readily break out. Often good water will help animals through a feed shortage, in that they turn to good account, with the water, such old dry grass as they would otherwise reject. Wells, brooks and pools are suitable for watering, the latter at the same time offer bathing facilities. Stagnant waters (ditches, pools) are generally unsatisfactory, as they often contain the eggs of intestinal worms. To prevent swampy banks,

wooden sticks, fascines or boards, stone, etc., are placed around the edges of the banks. If open streams are not available wells should be constructed, or the water should be hauled out to the pasture in barrels, which is not as difficult as would at first appear, since the need of water by animals that are on pasture is comparatively small.

The wells on pastures are sometimes constructed in such a way that they are set in action by the weight of the animal (Fig. 143). In this respect they have the advantage of being independent of any attendants. The pump piston is connected with a bridge-like platform placed in such a manner that it is movable. When the animal steps on the platform it presses upon the piston which each time lifts 20 liters of water that flows into the trough. When the animals step off the bridge the piston is raised again. The wells seem very useful for small cattle farms if the cost of construction is not too great. How satisfactory the wells would be with larger herds remains to be seen.

The watering places should be so arranged that they can be used for several pastures.

If, however, the animals are driven home in the evening, it usually suffices (excepting on hot, dry summer days) to water the animals early before driving them to pasture and in the evening after they have returned home. In addition to this, animals on pasture must be given ample opportunity to satisfy their desire for salt; this is to be recommended hygienically.

Supplementary Feeding

Whether grain should be given in addition to the pasturing depends on the pasture conditions. It is customary with calves under six months and with young bulls. Full-grown bulls are often given 2 to 3 kilograms of grain (oats with linseed meal, etc.).

Calves should generally not be pastured before they are six months old. Younger animals are better kept in a separate calf field or on a neighboring grass plot and an extra feeding given them until the sixth month. After six months of pasturing the increase in weight varies between 40 and 200 kilograms, the average being 120 kilograms. During midwinter young cattle should not be pampered and for economic reasons not be fed too much. It is advisable to feed them only hay, straw and turnips without grain. Young cattle kept without feeding grain not only overtake during the following pasturing period (on good pasture) those that have been fed grain, but even surpass them. "Lean to pasture and fat from pasture."

The accuracy of this rule is shown by the rearing experiments of Kofahl. The group that was fed grain gained on an average per head:

(a) During the winter period (grain)	55 kilograms
(b) On the pasture	86 kilograms
Total	141 kilograms

The group that was not fed grain:

(a) During the winter period	44 kilograms
(b) On the pasture	111 kilograms
Total	155 kilograms

Precautions

Animals should be prepared for pasturing. They should always be kept in cool stables so that they will go out to pasture with a warm coat of hair. Animals from warm stables need some time to accustom themselves to being out in the open. But it is just during the first period of pasturing that well-prepared animals make the best use of the pasture and gain the most weight. Pampered animals are unable to make use of this valuable time nor can they make up for lost time later on.

The shoes should be removed from horses during long periods of pasturing. This is always practicable. On the one hand injuries are avoided, and also the beneficial effect of pasturing on the hoof is aided.

In order to avoid the disadvantage and even serious injuries certain *precautionary rules* must be observed in the management of pastures.

The *change to pasture feed* as well as to all green feeds should be carried out gradually over a period of 8 to 14 days; likewise the return to stabling and dry feeding should be done in the same manner. If this is not done in the first instance bloating, indigestion and diarrhea often result, and in the latter case severe constipation. To avoid this animals in the stable that are no longer accustomed to green feed should be fed a little hay before they are sent out to pasture. Special care should be exercised in this direction during cold, wet weather and when pasturing on young grass meadows having a luxuriant growth fallow fields, new stubble fields, as well as clover fields. Even animals that have been on pasture must become accustomed gradually to clover, which is apt to cause severe bloating. Watering should be omitted shortly before and for several hours after feeding on this or other feeds that bloat severely. Care should be exercised even in changing from one pasture to another (lean to succulent, or vice versa).

Frosted feed in late autumn that easily causes colds and abortion among stable animals is digested without detriment by pasture animals that have been accustomed to it.

Fine sheep bred for wool are very sensitive to *dew-covered feed.* For this reason they are not driven out until the morning dew is gone and are driven home again before the evening dew comes.

It is advisable that during *rainy, cold weather* all pampered animals, especially young stock and pregnant animals, should be allowed in the open for only a very short time or should be kept in the stables entirely. A draft-free warm stable and abundant dry litter should be provided for animals that return drenched. Continuous fall rains may force an

early stabling of sheep. Sheep having fine wool are susceptible to severe drenching of their fleece; chlorosis and hydremia often result.

In general *forest pastures* do not compare in quality with meadow and field pastures; but even here great differences exist. The more open the forest the better the pasture is apt to be. The kinds of trees have different effects. Pastures in pine woodland are usually the poorest; in birch, oak and beech woods they are best, while those in fir and larch woods are medium. Plants that grow in forest pastures are mostly very poor in nutrients and are very woody, as, for instance, heather; others are rich in stimulating substances and in tannic acid. Forest pastures are best suited for hogs and cattle. Hogs feed in the woods on green plants, acorns, beechnuts, caterpillars, larvæ, etc. The danger of devouring the larvæ of *Echinorrhynchus gigas* is not so great in the open and must be accepted in the bargain together with the advantages.

Parasitic and Insect Pests, Etc.

Damp forest pastures are often dangerous for cattle. In some districts cattle easily acquire Texas fever, infectious redwater (hemoglob-

Fig. 144. *Ixodes ricinus* L. Natural size.

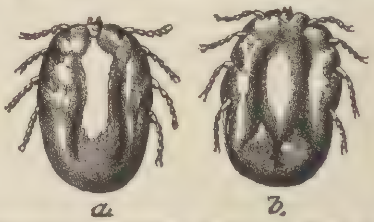


Fig. 145. *Margaropus annulatus*, female. *a*, Back; *b*, abdominal side (x 2).

inuria or *pirplasmosis*). This disease is caused by *Babesia bigemina* (*Piroplasma* or *Pyrosoma bigeminum*) which live as parasites in the red blood corpuscles and destroy them, at the same time releasing the blood pigment. This parasite is transmitted by the cattle tick which acts as an intermediate host. The ticks (*Ixodes ricinus*, Fig. 144, in northern European countries, and *Margaropus annulatus*, Fig. 145, in southern countries[1]) chiefly inhabit the damp edges of woods and swampy meadows that are overgrown with older thickets. They seek the cattle, bite mostly into the thinner places of the skin (inner surface of the thigh, etc.) and through their bite transmit the particular parasite. The indigenous cattle of these particular districts that have been reared amidst this danger tend to be immune or only become slightly affected, whereas newly imported animals suffer greatly from it and even succumb. To prevent Texas fever the meadow surface should be drained and made dry, which makes it impossible for the ticks to stay

[1] *Margaropus annulatus* is the tick found in the Southern United States and in other countries to the South. These ticks are being systematically exterminated in the United States by joint efforts of the Federal and State governments. The ticks are destroyed by dipping the cattle in arsenical solution.—J. R. M.

there. Without ticks there will be no piroplasmosis. The ticks should be removed from the animals and, wherever else they can be seized, should be destroyed. In districts that are especially menaced preventive vaccination according to Schutz is sometimes used. In an emergency especially dangerous sections must not be used as pasture for two years; the green feed should be made into hay which can be fed without harm.

Wet swampy pastures should if possible be avoided. They offer several dangers. Sheep easily contract an inflammation of the skin between the toes (interdigital dermatitis) with its resulting conditions which are commonly called foot rot. After a time pus germs and necrosis bacilli enter. The hoof partly loosens itself from the leathery skin, which partly dies off. This condition should be treated according to the principles of surgery. Since the disease can develop into an epizootic, the sick animals should be separated from the well ones and the stables should be thoroughly disinfected. To protect the well animals they should, when being driven out to pasture and home again, be driven through a box 2 meters long, about 1½ meters wide and 30 centimeters (12 inches) deep which has flat laths nailed diagonally on the floor and covered with a mixture of milk of lime, peat litter and 2 per cent lysol.

Fig. 146. Head end of *Strongylus equinus* with thorny wreath around oral opening (x 15).

Fig. 147. *Strongylus equinus*, male (*1-b*) and female (*1-a*).

A further precaution against mud scratches of sheep consists in the use of higher dry pastures (heights or slopes of hills) during wet weather. Cattle that are over one year old are better suited for pasturing on low-lying meadows and also during wet weather.

Furthermore, animals grazing on wet pastures occasionally take up with their feed the eggs of various *intestinal worms*, e. g., the palisade worms (*Strongylus equinus*), *Macracanthorhynchus hirudinaceus*, the liver fluke; among cattle the intestinal parasitic *Bunostomum* (Strongylidæ) which produces the bunostomiasis in Texas, Hungary,

Salzburg, Bohemia, etc.; lungworms, especially *Dictyocaulus filaria, Synthetocaulus capillaris, Metastrongylus elongatus, Dictyocaulus viviparus, Synthetocaulus rufescens,* which cause lungworm disease among sheep, goats, hogs, calves and game, and *Synthetocaulus commutatus* among hares and rabbits.

The palisade worm, *Strongylus equinus* (Figs. 146 and 147), is frequently found in the viscera of solipeds and sometimes causes dangerous aneurisms of the anterior mesenteric artery. According to Albrecht, almost every horse (in Alsace-Lorraine) harbors some kind of palisade worm, often two or three kinds at the same time. In such cases their eggs can usually be detected in the feces without difficulty. To do this take a small mass of feces about the size of a pea from a fresh fecal ball, spread this out with a few drops of water into a thin layer on a glass slide (mount) and examine it at a magnification of 100 to 150. The eggs can easily be identified by their oval shape, the double contoured, thin, transparent membrane, and the gray-black nucleus that is in the process of segmentation and is not equidistant from the outer membrane, especially at the poles. The length is 65-68 microns, the breadth 43-52 microns; *Sclerostonium quadridentatum* (*Strongylus equinus*) is somewhat longer (90-110 microns). They can always be easily distinguished from the Ascaridæ. The latter have their membrane surrounded by another thicker albuminous sheath, generally colored yellowish by the gall pigment (Fig. 331). If the mass of feces is prevented from drying out and is preserved 8 to 14 days, then drenched with clean water until soaked through and through, and some water still remains in the vessel, then after several hours larvæ that migrated into the water will be found in the liquid.

Warmth favors the development; cold retards it, but does not kill the eggs. At a temperature of 20° C. the embryo leaves the egg case in two or three days. The embryos are spiral shaped with a very long threadlike appendage and a conical-shaped front end. Their size is about ½ to ¾ millimeter. The larvæ pass through a stage of casting off their skin, and in so doing lose their long tails, and are then frequently called the rhabditis form. They often remain in the old skin for a long time and do not escape until they are in the host. They must, however, be matured before being taken up, or they will die in the host.

The larvæ are taken up through green feed, particles of feces, polluted litter or water. Whether, as with *Ancylostoma duodenale* of humans, entrance is gained through the skin has not yet been determined.

The fully developed palisade worms are thick-set, cylindrical, truncate, male up to 3, female up to 5 centimeters long; oral opening circular (Figs. 146, 147).

The severity of the disease sclerostomiasis (strongylosis), which is caused by *Strongylus,* bears a direct relation to the number of parasites taken up. Only a few parasites cause no apparent harm; many, on the

other hand, weaken the body, particularly in the case of foals. Strongyles can furthermore lead to the development of aneurisms of the an-

Fig. 148. Deer lung showing lungworms in trachea and bronchi. In the lobes of the lung are worm tubercles. (After v. Linden.) (About 1/6 natural size.)

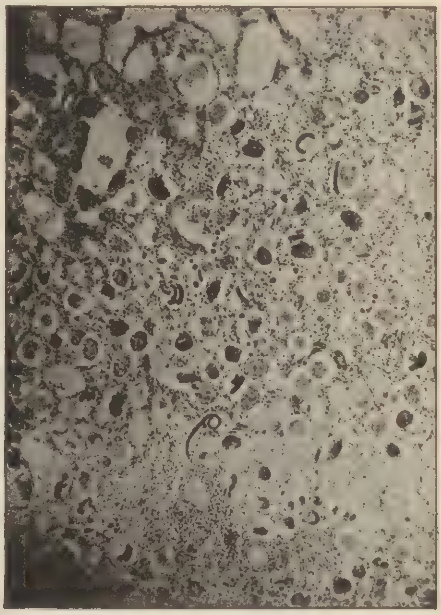


Fig. 149. Section through a worm tubercle in a deer's lung. In the lung alveoli are eggs and embryo of lungworms. The lung tissue is dense; in the lower part some alveoli are still to be found containing air. (After v. Linden.) (Enlarged about 30 times.)

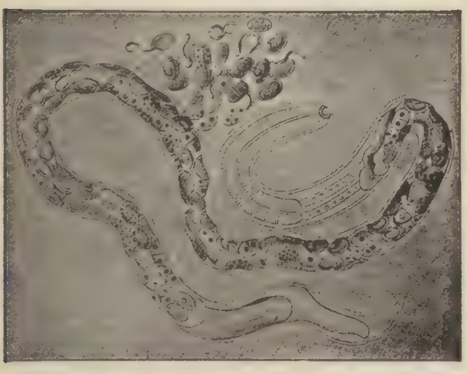


Fig. 150. Lungworm (*Dictyocaulus viviparus*). Female with eggs and embryos from trachea of deer. (After v. Linden.) (Enlarged about 200 times.)

Fig. 151. Lungworm egg with embryo. (Enlarged about 90 times.)

terior mesenteric artery, to fatal embolism in the vascular system, to a migration under the peritoneum, into the retroperitoneal fatty tissue, into the testicles, liver and lung, and there lead to the development of

parasitic, gray, transparent fibrous or calcareous small tubercles (nodules). The tubercles often resemble glanders tubercles.

To prevent strongylosis it is advisable to filter the water. With this method Mieckley had good results in Beberbeck. First of all the horses should be examined for these intestinal parasites. Those having worms should be kept off the pasture or exercising lot until they have been successfully treated for worms. Albrecht found tartarus stibiatus to be ineffective for this purpose and recommends 80 grams oil of turpentine with 500 grams castor oil. The worms that pass off should be burned. The feces should of course be removed from the stalls. The permanent bedding should be renewed frequently or be replaced by ordinary bedding.

The *causative agents of lungworm, stomach worm and intestinal worm diseases* develop in the damp earth from the embryos, discharged with the feces, into microscopic, independent worm forms which multiply rapidly, are very resistant against drying out and remain viable for years. They are supposed to be taken up through grass, perhaps also, as with *Ancylostoma duodenale* with humans, through the skin. Through the blood and lymphatic vessels they are then carried to the lungs, where they develop into the well known filaria. A few species may attain a length of 8 to 10 centimeters. The full-grown lungworms inhabit only the air passages (Fig. 148), their numerous embryos the alveoli (Figs. 149, 150). They cause obstructions (worm knots) and catarrh. If they appear in large numbers they will also be found in the intestines (cause diarrhea), in the liver, lymph nodes and heart's blood.

To prevent lungworm and stomach worm diseases the animals afflicted with the worms should not be allowed on the pasture, or they will infest it for years to come. The worm carriers are in this case also easily determined by a microscopic examination of the feces. The eggs and young embryos of the worms are found in the feces (Fig. 151). Dangerous pasture land should always be avoided.[2] Wet pastures should either be made dry through drainage, which makes it impossible for the embryos of the intestinal worm to develop, or they should not be used for pasturing at all, especially when the warmer weather sets in. The grass grown on such swampy meadows should not be fed in the barns in a fresh, succulent condition, but should be used as hay. Worm diseases have not been known to result from feeding the hay from swampy meadows. If it is necessary to use swampy meadows for pasture, then only such animals should be put on them as are soon to be slaughtered. The manure of infested stables should not be scattered on the meadows, but upon high, dry fields. A further precaution against the diseases caused by intestinal worms consists of the destruction of the intestinal worms in all the stages of their development in which they can be found. To destroy the embryos and their intermediate hosts as well

[2]In eastern Germany, where hundreds of sheep are raised on large estates, the sheep managers must give a security, which is not paid back until during the course of the winter when it has been shown that there has been no negligence in the watching of the sheep.

as certain harmful insects, various individuals recommend keeping poultry in movable houses on the pastures.

A good state of nutrition favors resistance to worm diseases. For protecting sheep it is recommended that they be given lupines or rye-lupine bread (made of 20 liters each of rye flour and lupine flour, 1 pound gentian-root powder, 2 pounds copper sulphate and 4 pounds ordinary salt) as an extra feed, or the three last-mentioned powders mixed for licking. Copper licking salt (10 grams daily for a sheep or goat, 30 grams per head of cattle) according to Von Linden, has also proved satisfactory. Copper licking salt consists of 1 part copper chlorid or sulfate and 99 parts rock salt[3].

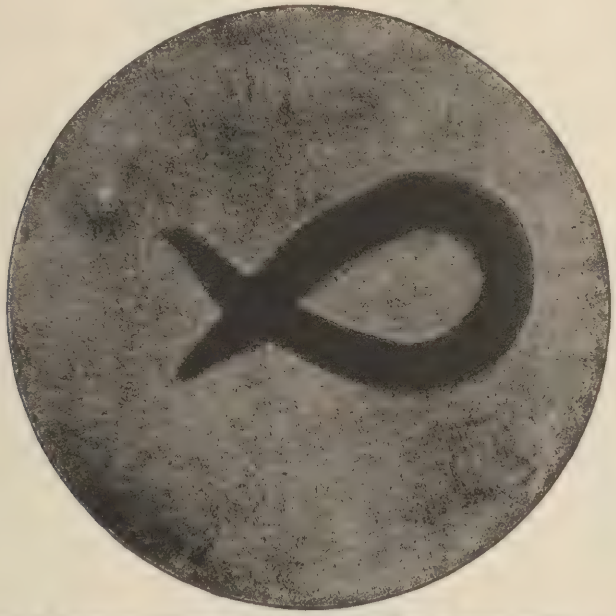


Fig. 152. Larva of lungworm (*Dictyocaulus viviparus*), from a worm embryo of a deer's lung and cultivated on sterilized earth. (After V. Linden.) (Enlarged about 300 times.)

Infected meadows should be fertilized repeatedly with Thomas meal, calcium nitrite, Chile saltpeter and liquid horse manure or should be disinfected with iron sulphate (300-500 kilograms to 1 hectare, or 300-500 pounds to the acre). These fertilizers injure and finally kill the free-living generations of the lungworms. Since game also suffers from lungworms and intestinal worms, all necessary precautionary measures should be observed to avoid an infestation of the game through the domestic animals and vice versa.

[3]For the protection of sheep against stomach worms, Curtice, of the United States Bureau of Animal Industry, recommends dosing the animals every four weeks throughout the year with bluestone solution (copper sulphate). A stock solution is prepared by adding 1 pound of coarsely powdered bluestone to 2 quarts of boiling water. This is diluted for use by adding 3 quarts of water to 4 fluid ounces of stock solution (for 25 sheep). The dose is 4 ounces of the diluted solution for a sheep weighing 80 pounds or more.—J. R. M.

Liver fluke disease appears chiefly among cattle and sheep, less often among goats, hogs, horses and game. It occurs in all parts of the world, but is restricted to damp, swampy places. During wet years it assumes the character of an epizoötic and causes great losses among grazing animals.

Fig. 153. Glimmer larva (*Miracidium*).

Fig. 154. Sporocysts.

Fig. 155. Redia with "daughter redia."

Fig. 156. Redia with Cercaria.

Fig. 157. Cercaria.

Fig. 158. Large liver fluke (x 1/3).

Fig. 159. Small liver fluke (natural size).

Fig. 160. Dwarf snail (natural size).

Animals that have become severely infested lose their appetites, become weak, anemic, grow thin and usually die after 3 to 6 months with dropsical conditions and debilitation. The causes are the large liver flukes, *Fasciola hepatica* (formerly called *Distomum hepaticum*) and the small liver flukes, *Dicrocœlium dendriticum* (Figs. 158 and 159). The ciliated

larva (*Miracidium,* Fig. 153) develops only on damp ground and at a minimum temperature of 8-10°C. from the eggs discharged with the feces of the animal host. For further development, the embryo must penetrate an intermediate host (dwarf snail, *Iimnaeus minutus,* Fig. 160, for *Fasciola;* for *Dicrocœlium dendriticum* the intermediate host is still unknown). In the intermediate host the ciliated larva develops into a sporocyst (Fig. 154); within the sporocyst a new generation develops, the redia (Fig. 155), and within this the cercaria (Fig. 156), which again leaves the snail. The cercaria has a tail-like appendage (Fig. 157), can live independently in water, and consequently can be carried great distances. After some time the cercariæ settle down on blades of grass or water plants and change into cysts. In this form they are again taken up by the animals. The gastric juices dissolve the cyst membrane, the parasites are set free, penetrate the intestinal wall and wander in the abdominal cavity toward the liver, into which they penetrate as far as the bile ducts.

To prevent distomiasis the following measures are recommended: Avoid infesting damp pastures. If infestation does occur, determine by microscopic examination of the feces for worm eggs (Fig. 33, a, d) which animals are the worm carriers. Worm carriers may graze on dry meadows, as further development of the parasites is impossible there. Draining the pastures; destruction of the intermediate hosts by means of fertilizing with lime, calcium nitrite or liquid horse manure; making hay of the grass (cysts die); giving cattle salt with the addition of copper chlorid, which kills the young stage of the liver fluke. For treatment Marek recommends distol to be taken internally (for 1 kilogram of live weight of cattle 0.025-0.037 gram; for sheep and goats 0.065-0.095 gram, once a day for four or five days).

Animals on pasture can moreover also take up the eggs of various *cyst-forming worms or bladder worms,* such as *Multiceps multiceps* (brain cyst worm, the cause of gid in sheep). *Echinococcus, Cysticercus tenuicollis,* cellulosæ and *C. bovis* (hog and cattle measles), which more or less injure the health of the animals and above all their value as slaughter animals.

A person afflicted with a tapeworm must be considered as a source of infestation for cattle and hog *measles.*[4] It is most advisable, in the interest of the person carrying a tapeworm, that he submit to a tapeworm cure and then burn the discharged tapeworm. As a precaution human feces that may contain tapeworm segments or eggs should not be used as fertilizer upon pastures but upon dry grain fields.

By means of stringent combative measures it has been possible during the last few years to suppress intestinal worms considerably and almost entirely exterminate them (*Cœnurus cerebralis*). In this respect hy-

[4]The human tapeworm, *Taenia saginata,* resulting from eating raw beef containing *Cysticercus bovis,* is very widespread, but *Taenia solium,* which results from eating raw pork containing *Cysticercus cellulosae* ("measly pork"), is exceedingly rare in the United States and England but comparatively common in North Germany.—Translator.

giene has found a faithful ally in meat inspection, whose duty it is to remove harmlessly all intestinal forms that are found.

Pasture animals are also threatened to a certain extent by parasitic articulated animals and insect larvæ. The following larvæ of *insects* that are parasitic on farm animals will be mentioned here:

The larvæ of the horse bot-fly (*Gasterophilus intestinalis, G. pecorum, G. hæmorrhoidalis* and *G. veterinus, hasalis,* Fig. 161), which are parasitic in the stomach of the horse. The larvæ of *G. hæmorrhoidalis* also abides in the rectum near the anus for some time before leaving the animal host[5].

The larvæ of the sheep bot-fly (grub in the head, *Æstrus ovis*), which in the subcutaneous connective tissue of cattle (Figs. 162, 163), and sometimes in horses.

Fig. 161. Horse bot fly. *a*, Developed insect; *b*, hair with eggs attached; *c*, undeveloped; *d*, developed larvae (slightly enlarged).

The larvæ of the cattle warble fly, *Hypoderma bovis,*[6] which is found are parasitic in the nasal, frontal and maxillary sinuses of sheep (Fig. 164).

The swarming time of the horse bot-flies occurs in the months of July, August and September (especially during the hot, sunny noonday hours). The female deposits her cone-shaped black or white eggs of 1 millimeter in length (Fig. 161, b) on the hair and glues them tight to it. The little larvæ that emerge are licked off or crawl actively into the oral and nasal orifices and thus get into the stomach or into the first part of the small intestines, to whose mucous membrane (less often to the pharynx) they hook themselves fast with both head hooks (Fig. 161, d). They remain there for about 10 months and develop into cylindrically shaped larvæ of 1.3-2.0 centimeters in length with a dull pointed anterior end and blunt posterior end; short bristles are located along the bands that pass around the body. After the larvæ development is com-

[5]Hutyra and Marek, in Pathology and Therapeutics of the Diseases of Domestic Animals, vol. 2, p. 486, refer to *Gastrophilus pecorum* as the cattle bot-fly and to the *Tabanidæ* as gad-flies On the other hand, Webster's International Dictionary states that any of the *Oestri* are gad-flies, including the bot-fly of the horse.—Translator.

[6]In the United States a related species, *Hypoderma lineatum,* is more common.—J. R. M.

pleted they release their hooks and pass out with the feces, change into a chrysalis in the ground, to be transformed after 1½ months into the perfect insect (Fig. 161, a).

The larvæ of the bot-fly when occurring in small numbers seldom cause a manifest illness. At times the rectal bot larvæ (*Gasterophilus hæmorrhoidalis*), due to their stopping for a while at the anus, cause a severe

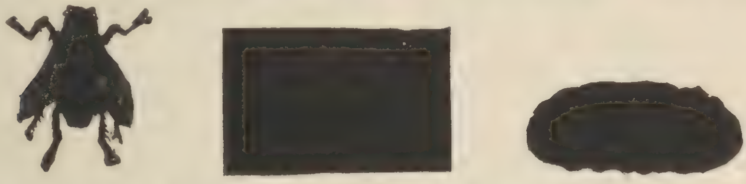


Fig. 162. Cattle warble fly. *1*, Female fly; body black, wings brownish, hairs on head and anterior part of breast black, posterior part of abdomen gray in front, black in middle and behind reddish yellow. (Natural size.) *2*, Young larva of warble fly from subcutaneous tissue. *3*, ripe warble fly larva, color brown-black. (After Kais.)

pruritis, rubbing, excitement and straining, so that even a prolapsed rectum may result. If the bot-fly larvæ appear in very great numbers they can lower the nutritive condition of the animal. On the other hand there is seldom evidence of severe illnesses of which they are the direct cause (as colic, fatal perforation peritonitis, severe and even fatal bleed-

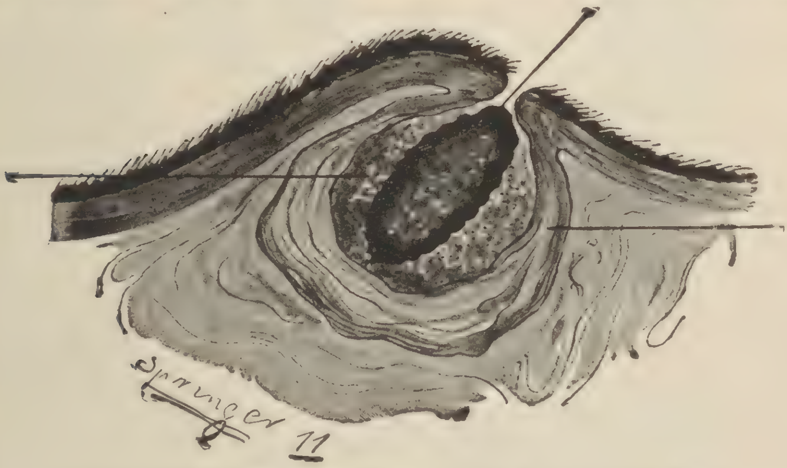


Fig. 163. Section through mature warble. (Natural size.) (After Kais.)

ing after arteries have been pierced, cases of strangulation due to the larvæ hooking themselves into the mucous membrane at the entrance to the larynx).

To prevent the entrance of the larvæ of the bot-fly it is advisable to carry out a regular, careful grooming of the skin, even with horses on pasture, during the swarming time of the fly, removing the eggs and larvæ.

The cattle warble fly (Fig. 162, 1), swarms from June until September and particularly during the hot noonday hours. The females glue their eggs to the hair of the cattle. The larvæ that develop from these eggs are seen after later observation to have wandered to the oral cavity or have been licked off and swallowed by the cattle. In this way the larvæ reach the pharynx, where they remain and grow for three months. They gradually bore through the pharynx and toward spring gradually work their way to just below the skin of the cattle. According to the observations made by Stub and Glaesser, the larvæ bore through the skin, wander about for some time under the skin through the connective tissue, whereby some go astray and reach the pharynx and spinal medullary canal, while the majority remain at rest and develop "warbles." The larvæ produce the so-called warble in the subcutis (Fig. 163). In the meantime the larvæ have attained a breadth of 12-15 millimeters and a length of 28 millimeters and can be identified by the two rows of longitudinal elevations that are visible on the left and right sides of the back. The larvæ bore through the skin of the warble and, leaving their parasitic existence of 10 months' duration in the animal, generally during the early morning hours, they fall upon the ground, burrow into it a short way, change into a pupa, and finally, after 20 to 30 days, change into the fully developed insect.

The disadvantages of the warbles consist chiefly in a decrease in value of the perforated hide and in a decline of the nutritive condition (Glaesser). The milk yield is seldom affected and only when the parasites are very numerous. The yearly loss (hide and meat) caused by *Hypoderma bovis* is estimated at 6 to 8 million marks ($2,520,000 to $3,360,000) in Germany, at $6,725,000 in England and at $16,810,000 in Ireland. In certain warble fly districts in northern Germany about 75 percent of all cattle are afflicted with the larvæ.

To prevent this fly plague a careful grooming of the skin is recommended. Unfortunately, this cannot be done sufficiently on the pasture, any more than the advised and not very efficacious sponging off with a vinegar decoction of walnut leaves or a mixture of asafetida and diluted vinegar. The surest cure is the annual opening of the boils, i. e., splitting and squeezing out the warble with the destruction of the larvæ before the animals are put out to pasture (end of March and April).[7] If possible the treatment should be repeated after intervals of three weeks as long as new warble boils develop. In Oldenburg, Mecklenburg and other warble fly districts the systematic removal of the larvæ from the boils has proved satisfactory; in many cases the proper management of this treatment has led to a complete eradication of the warble fly

[7]Hadwen points out the danger of bad after-effects if the sac containing the larva is ruptured or if the larva itself is ruptured in extraction. These are due to toxic properties of proteins in the larvæ. He advises care in extraction, first softening the skin with water and then squeezing the warble sac. If necessary round-ended forceps may be used to stretch the opening and extract the larva. If a larva is ruptured accidentally the parts should be washed quickly to dilute and remove the toxic material.—J. R. M.

larvæ. According to Von Joechle's experiments, the larvæ in the warble boils can be killed by treating with gaseous sulphurous acid.

To prevent *sheep grub* disease (grub in the head) caused by the larvæ of *Œstrus ovis*, pastures wooded with deciduous (not needle-bearing) trees and their vicinity should be avoided from the middle of June until the middle of September, and especially during the hot noon hours, for it is in such places that the gadflies of the sheep prefer to abide and where they swarm. Leaved trees and bushes should if possible be exterminated from sheep pastures. It is furthermore advisable to smear tar around the nostrils of sheep during the swarming time of the flies, so that the progeny of the flies deposited there will stick fast and not be able to wander into the nasal cavity. All gadflies of sheep and their larvæ (Fig. 164) that can be seized should be exterminated.

Of the articulated animals which in their fully developed stage are to be considered as temporary parasites of pasture animals, the following are to be mentioned: The sheep tick or sheep louse fly (*Melophagus ovinus*), the spider fly or horse louse fly (*Hippobosca equina*), various stinging flies (*Stomoxys calcitrans*, etc.), Tabanidæ (often erroneously

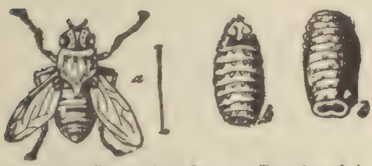


Fig. 164. Sheep bot fly. *a*, Developed insect; *b* and *c*, developed larva.

Fig. 165. Sheep tick (sheep louse fly).

called gad-fly), sweat flies, various kinds of gnats, among which the Kolumbatz fly[8] (*Simulia maculata*) and *S. reptans* (black fly or brulot) are the most dangerous. There are also dog ticks (*Ixodes ricinus S. reduvius*) and sheep and cattle ticks (*Margaropus annulatus*) which must be taken into consideration not only as temporary bloodsuckers but above all as carriers of *Piroplasma bigeminum*, the cause of epizoötic Texas fever.

The *horse louse fly, Hippobosca equina* Geer, is 8 millimeters long, brown in color with three yellowish spots on the hairy posterior part of body; the legs are rust yellow with brown rings and have hooks on the split feet and pedal balls; the large wings are reddish and stumped, projecting beyond the posterior part of the body. The horse louse fly occurs during summer and fall on horses and cattle, seldom on dogs, particularly on the inner side of the hind leg and on the anus, and causes restlessness of the horses through its stings.

The *sheep tick* (sheep louse fly), *Melophagus ovinus* (Fig. 165), a sucker, occurs mostly on forest and grassy pastures, seldom on field-pas-wingless, rust-yellow insect of about ½ centimeter in length, is a blood-

[8]A European fly, similar to the American buffalo gnat.—Translator.

tures; it never stays in clean, well-kept stables. It annoys sheep and causes them to rub themselves, which results in more or less injury to their fleece. According to Noeller, the sheep tick is also the means of transmitting sheep trypanosomes. A carbolic or creolin bath is recommended as a remedy.

Sponge baths of a vinegar decoction, of walnut leaves, carbolized oil, emulsions of asafetida, fly oils, etc., are recommended against the *stinging flies* or gadflies (*Tabanus bovinus* L.) which not only annoy animals but with their stings can transmit disease germs (anthrax bacilli), puss germs, etc., as well as rather harmless *Trypanosoma theileri* of cattle and perhaps also blood filaria, and in the tropics the dangerous surra and nagana or the disease caused by the tsetse fly (*Trypanosoma evansi* or *T. brucei*); in the locality of Dresden, Germany, the larvæ of the threadworm, which are said to be the cause of summer sores, also *Habronema megastoma*, etc.

The most sensitive parts of the horse (belly, public region, around the eyes) are rubbed with the sponge-bath preparations mentioned above. The protective effect lasts but a short time. According to Sustmann it lasts half an hour in the open and 1 to 2 hours in stables. Further recommendations are, a filtered infusion of 400 grams of potash, 500 grams of walnut leaves, 100 grams asafetida and 100 grams cloves in 10 liters of hot water; or a mixture of 50 grams napthalene, 25 grams laurel oil, 25 grams acetic ether and 200 grams of tincture of insect powder; or 700 grams turpentine resin, 500 grams soft soap, 100 grams fish oil and 10 liters of lukewarm water. The separate ingredients should be mixed thoroughly in the order given; the water should be added gradually with constant stirring. The mixture should be applied with a brush. Sapo ex oleo animali fœtido, a water-soluble 25 percent saponification of oleum animale fœtidum, as well as cod-liver oil (lasting effect about 10 hours) can also be used for this purpose. Lastly, the insect powder "Pol-Mac" is also used, which also renders certain death to lice, fleas and sheep ticks (sheep louse flies) and keeps away bird mites. Furthermore, fly nets and the like are recommended; the results are, however, far from satisfactory. It is taken for granted that all flies, their larvæ and pupæ, will be destroyed wherever possible. The most successful means of control results in an appropriate protection of birds, such as providing nesting facilities (bird houses), feeding the birds during the winter, establishment of thickets for their protection, etc. Besides these measures, swamps and moors should be drained.

Sweat, carrion and meat flies (blow flies) occasionally deposit their eggs in wounds and boils as well as in the genital and anal openings, where their larvæ then develop; annoyance of the animals and inflammation of the particular parts result. An efficient treatment of the skin is the best method of combating this trouble.

Animals are also troubled by still other flies (*the golden fly, storm fly,*

etc.) which at times settle on and in their eyes and ears, thus producing a possible inflammation of the eye and auditory canal. The application of fetid animal oil (fly oil) is considered the best preventive.

Still more dangerous are the *stinging gnat-like flies,* especially the Kolumbatz fly as well as the black fly (*Simulia reptans*). These gnat-like flies often attack the animals while on pasture (cattle and horses) in dense swarms, and individual ones even penetrate into the body orifices (eyes, ears, mouth, anus and vagina), where they sting and suck blood. Cattle and horses in attempting to escape from them run about until exhausted. When the gnats bite they discharge an acrid substance into the wound which causes a severe, painful swelling. Often the animals that have been badly stung about the eyes, on the lower side of the neck, navel, udder, inner surface of the thighs, on the perineum and on the exposed genital organs, die sometimes within half an hour in great pain from suffocation or poisoning after preceding excitement, weakness, dyspnea, high fever, slow pulse, palpitation of the heart and convulsions. Later during the course of the attack the temperature and number of respirations decrease occasionally below normal limits. Postmortem examination shows hemorrhages in the subcutaneous connective tissue, in the loose connective tissue around the larynx and pharynx, in the pericardium, heart, etc. This condition may be distinguished from anthrax by the blood being clotted and the spleen tumor lacking. In addition cloudy swelling of the liver and heart are found, hyperemia of the pia mater and sometimes dropsy of the brain.

The small Kolumbatz flies of about 3 millimeter in length have their abode in the lowlands of Donau but at times find their way into Bohemia, even to Anhalt and northern Germany. They prefer wet places covered with brushwood. They are especially dangerous on sultry May days (explosion-like development of the swarm); later they still swarm but then generally cause no important harm. *Simulia reptans* (black fly) is more prevalent in Germany then the Kolumbatz fly. According to information given by Friederichs, it was probably not *Simulia reptans* but more likely *S. argyreatum*. The black fly has repeatedly appeared in great numbers in various districts of northern Germany. In the vicinity of Neustadt on the Rhine, for example, in the year 1916, 132 cattle and 3 horses died. According to Damman and Oppermann, the black fly transmits bovine hemorrhagic septicemia (?), and according to Railliet *Filaria papillosa* (*Steria equina*). The larvæ of this gnat live in running water, where they are fastened by a thread spun on water plants, stones or pieces of wood. They exist through the winter in the larval stage and are a favorite food for young trout. At the end of April and beginning of May they change into a pupa, and about eight days later the insect emerges. The female lays as many as 200 eggs at each of three different times. The black fly seeks particularly reddish brown cattle and on them

especially the bare parts of the udder. Their chief swarming time is in the evening toward dusk. They seldom attack people.

A very disagreeable kind of gnat, which is seldom taken into consideration in veterinary literature, is the *midges* (Chironomidæ). Among these there are first of all Ceratopogonines. These are blood-sucking gnats of 1 to 3 millimeters in size and have spotted wings. They frequent the edges of woods. The larvæ live in water. Those of most consequence in Germany are *Ceratopogon,* variety Winnertz, 1 millimeter in size, *C. pulicoris* L. Flohchnacke, 2 millimeters, very common, also in England and Sweden *C. stigma* Meigen. They attack and suck blood from people, especially around the edge of the hair on the head, as well as in great numbers on cattle and game. Their chief time of swarming is from May or June until September, during the evening hours from 7 to 9:30 o'clock. With cattle they prefer the head, inner surface of the hind legs, the udder and belly. Blood-sucking midges also exist in Brazil and India.

Finally the true *stinging gnats—mosquitoes—Culex* and *Anopheles,* should be mentioned here. They attack humans and animals in the open as well as in the stables. *Anopheles* transmits the human malaria, *Culex* the avian malaria. In the tropics *Anopheles* are also carriers of filaria of domestic animals, whereas in Germany neither of these gnats plays any part as carriers of diseases of animals.[9]

As a prevention against these severe gnat plagues in especially endangered districts the animals should, if possible, be left in the stables on sultry days during the swarming time (from sunrise until about 10 o'clock in the morning and again toward evening, or should at least be kept away from the neighborhood of swampy woods. Attempts should be made to drive the Kolumbatz flies away from the meadows by means of a smudge of straw, leaves, dried manure or half-dried wood. Furthermore, by smearing those parts of the animals that are especially endangered (mouth, nose, eyelids, sheath, neck, and the inner surface of the thighs) with petroleum or with a mixture of equal parts of wood tar, spirits and linseed oil or kerosene, fetid animal oil and fish oil, or with fly oil, we can attempt to keep the gnat plague away from animals. The inunction should be repeated every five or six days. The treatment consists of rubbing off the attached gnats, of giving internal doses of stimulating remedies (strong coffee or injections of caffein), as well as sponging off the animals with spirits of camphor. Furthermore, the eggs of the gnats should be destroyed. This can be done successfully by diminishing the flow of water and deepening the stream, or by the removal of flat places along the banks. The most radical method is the drainage of pools, ditches, etc. In the province of Hanover it has been observed that animals pastured early are stung by *Simulia reptans* but are not killed by the sting. According to that, early pasturing and hardening are to be

[9]*Culex* is said by Stitt to also transmit filaria as well as malaria. It is also implicated in dengue.—Translator.

recommended, so that the animals have become accustomed to the gnats before the swarming time occurs, or have become immune to the poison of the gnats.

Attention is also called to the stings of *bees,* which, if in great numbers, can also cause severe illness and even death of horses. The poison from bees shows a certain relation to sapotoxin and cantharidin.

The bites of *poisonous snakes* should also be mentioned. Horses that have been bitten on the head by a horn viper develop a severe swelling of the face. The dyspnea has been overcome by tracheotomy. Recovery occurred followed subcutaneous injection of potassium permanganate near the place where the horse was bitten.

It is fitting to refer again to the *injuries from feed,* discussed on pages 99-102, and to emphasize especially that the land to be used for pasture should not be a carrier of bacterial soil diseases, as, for example, of anthrax and blackleg.

Meadows infected with *anthrax* and *blackleg* should not be used for grazing by animals that are susceptible to these diseases. The ground should be drained to prevent the development of anthrax and blackleg bacilli. The grass crop can be dried and with relatively small danger be used as hay. If the particular acreage is badly infected it should be utilized as grain fields or entirely withdrawn from agricultural use and planted into woodland. If this is impossible for economic reasons, and if the land must be used as pasture, the animals should be immunized (vaccinated) before being put out to pasture. Primarily, however, care must be taken that the ground does not become infected. The animal excreta and the carcasses of animals that have died of anthrax or blackleg should not be buried in the field but should be burned. If it does become necessary to bury them, the instructions already given (p. 70) should be followed. The waste waters from tanneries, etc., which contain foreign raw animal materials, which are known from experience frequently to contain anthrax spores, should be disinfected before they are allowed to drain into rivers.

Lastly, *chemical poisons* must not be overlooked. The danger of poisoning from fertilizing substances has previously been discussed (p. 53). In a case cited by Schmitt a cow devoured calcium carbide on the pasture. This had been scattered on the meadow by people from the mountains when they emptied their lamps. The cow became sick with a fever (41.2°C., 106.2°F.), rapid heart action, trembling, groaning, suppressed appetite, diarrhea. Recovery was effected with caffein injection, flax-seed gruel and doses of sodium sulphate.

B. Exercising Lots

As has been previously mentioned, exercise in fresh air is very necessary in the care of younger and older animals. If it is impossible to work animals in the open or to turn them out to pasture, then at least an

exercising lot should be provided for them. Exercising lots are, however, inadequate substitutes for pastures, since they perforce are limited to less space and are lacking almost entirely in fresh, nourishing green feed. The lot allowed for foals and young stock should be at least 100 square meters.

In constructing an exercising lot (paddock) for *horses* (foals, horses for breeding purposes, and convalescent horses) the following points should be noted:

For mares with sucking foals and for foals that have been weaned the exercising lot should not be a great distance from the stable; for older foals it may be farther distant.

The location should be such that it is protected against north and east winds (in Germany). In an emergency a stone wall may be constructed to effect this.[1]

The ground should be dry and preferably grown over with grass. Damp, swampy ground induces the development of flat hoofs and bear-like, clumsy postures. By draining, leveling, or filling in with soil or sand the swampiness can be eliminated. For inclosing the areas, fences made of wooden poles and hedges, 1.5 to 2 meters high, of hornbeam, hazel-nut, maple and common beech are to be recommended. The wooden fences should be erected as follows: Posts, preferably of hardwood, 2.5 meters (yards) long and 15 centimeters (6 inches) in diameter, should be charred at the lower end or saturated in carbolineum, etc.; they should then be sunk into the ground to a depth of 1 meter and at intervals of 2.5 to 3 meters apart and then be tamped firm. The posts are connected by 2 or 3 horizontal bars, spaced suitably, or by barked poles 8 to 10 centimeters (3 or 4 inches) in diameter. To prevent injury of the animals the poles or boards are often fastened with willow bows or wooden nails. Wire, especially barbed wire, should not be used for this purpose; they often cause injuries. For the same reason hedges of hawthorn, buckthorn, and blackthorn (wild plum) are not so good as those mentioned above. Hedges of pines and firs should also be avoided, as the young shoots when eaten by the animals irritate the digestive apparatus and the kidneys.

The size and shape of the exercising lot should be selected so that the horses can run straight ahead at a trot and gallop for 25 or 30 meters. Therefore long, narrow inclosures are preferable to square ones if it is necessary to limit the space. If the animals are to spend the entire day in these exercising places, cribs and hay racks should be constructed in the corners. Shelter against the burning rays of the sun should be provided for the animals by means of shade trees (lime or linden, chestnut, oak, etc.) or with shelter sheds, closed on the side toward which the prevailing winds blow. These sheds (Fig. 136) also serve as a protection against rain.

[1] In the United States protection should be particularly afforded against the north and northwest.—Translator.

In order that the horses may make proper use of their exercising ground it is necessary to see to it that they actually do exercise and not merely stand about quietly in the inclosure. This is often accomplished by putting several foals into the inclosure; they then excite one another to motion. Perhaps they may actually have to be driven to a trot or gallop with a whip, which would be the more necessary the shorter the time that the animals can spend in the inclosure.

At the first evidence of sexual excitement the animals should be separated according to the sexes.

To produce a healthy, sturdy, resistant breed of *cattle*, pasturing, or, in an emergency, exercising lots, are essential, especially for the young stock. But daily exercising for at least an hour in fresh air is also very beneficial for the health of milk cows. The milk is improved by it. The relative and absolute fat content of the milk is increased by moderate exercise, even though total yield of milk may be considerably lessened.

In establishing exercising lots for cattle the same general principle may be applied as for those for horses. It is not necessary to be so particular with regard to the ground. Cattle do very well on a damp, although not swampy ground. For inclosing the lot barbed-wire fences are often preferred. It is perhaps more necessary to incite lazy young cattle to exercise daily for half an hour to an hour than is the case with lively colts.

Since *sheep* are usually kept on pasture, the question of an exercising lot for them need hardly be considered. For them dry, firm ground would be necessary. Swampy ground easily causes purulent inflammation in the interdigital space. Woodland sites should be avoided, since these, as well as the crevices and holes in the woodwork of sheep stalls, are frequented during the hot summer months by sheep flies (*Œstrus ovis*), which deposit their eggs and larvæ about the nostrils of the sheep. The larvæ that are already in the process of emerging when the eggs are deposited crawl up into the nasal, forehead and maxillary cavities, hook themselves fast in the mucous membrane and produce severe purulent and even necrotic inflammations as well as inflammation of the meninges (gid), which may result in the death of the sheep. As a preventive it is advisable to exterminate the thickets in the neighborhood, to destroy the flies nesting in the sheep stalls (with formalin or milk of chlorid of lime), to smear the nasal orifices and upper lips of the sheep, especially of the lambs and yearlings, with tar, and to destroy the larvæ and flies wherever possible.

If conditions are such that *hogs* can not be put on pasture, it is very beneficial to them to be at least given exercise now and then in the fresh air. For this purpose the hogs should occasionally be let out into the farm yard. Great care should be exercised when doing this so that they find no opportunity to root in human feces nor to eat them. The latter might contain segments of *Tænia solium* with numerous eggs if the

[2] Very rare in the United States and England.—Translator.

humans concerned are afflicted with this tapeworm.[2] From the eggs taken up by the hogs the young embryos (oncosphæres) escape after the egg case has been digested; they then migrate from the intestine into the connective tissue of the muscles, etc., to change there into the pork measle (*Cysticercus cellulosæ*). The value of the hog for slaughtering purposes is greatly lowered if not entirely destroyed. Great care should therefore be taken that hogs have no opportunity to root in human excrement. If any one residing on the farm is afflicted with a tapeworm it is most advisable that he be subjected to a treatment to eradicate the tapeworm as soon as possible. It is far better to arrange a special hog lot for the hogs, where they stay all day and also during the warm time of the year, all night. The hog lot should best be in direct connection with the sties. The fencing in is accomplished by low walls or strong planks.

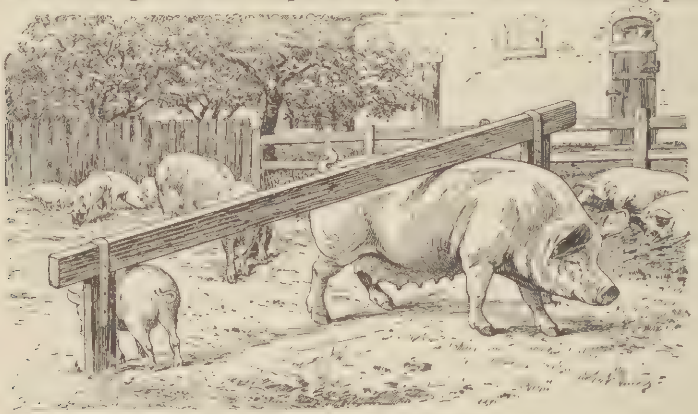


Fig. 166. Rubbing frame or bar.

The ground should be porous to prevent it from becoming swampy, otherwise it should be drained. If in spite of this a swampy condition arises, the swampy places should be dug out and be filled in with sandy soil. To prevent the ground from becoming marshy soon there is nothing else to do but to partly pave the lot; a portion should, however, be left unpaved to allow the hogs to follow their natural desire to root. A shallow concrete water trough, if possible with an inflow and outflow, is very necessary in the hog lot. To complete a hog lot a rubbing post should be erected. Frequently two posts are set in the ground, one 1 meter (yard), the other 30 centimeters (1 foot) in height, and set 1.5 to 2.0 meters apart, and connected by a sloping beam. The latter makes it possible for the animals to scrape or rub their backs (Fig 163).

Lastly, provision should be made for shade. If the pigs can not find shelter from the burning rays of the shun in shade afforded by buildings, then a lightly constructed wooden roof should be erected, or trees should be set out. Oaks and beeches should be avoided, as they are a favorite resort of the May-bug, which acts as an intermediate host for *Echinorrhynchus gigas*, an intestinal worm of hogs.

Section VII

The Stable

The stable serves as a place of abode for agricultural animals and protects them against the inclemencies of the weather, but on the other hand it should not become a source of danger to the animals' health. The fact that a great many animals must remain more than half of their lifetime in the stable, and many almost their entire life, for economic reasons (increase in productiveness, facilitation of their use, etc.), robs the animals more or less of the influences of light, which are so extremely important for their good health; of the pure air rich in acids, and of exercise, and forces them to live closer together. This involves several dangers, such as a decrease in the power of resistance, favoring the possibility of the transmission of contagious diseases, etc. In order that the disadvantage should not exceed the benefits which are supposed to be derived from stabling, it is necessary that the stable possess certain qualities described more in detail in the following pages.

I. Building Site and Location

If possible the site should be chosen so that the stable has an open position which allows free entrance of light and air.

The subsoil of a stable should be dry so that the ground water in rising does not reach the foundation. For this purpose a site slightly higher than the surrounding land is preferable. Care should be taken not to build too near steep slopes, depressions, swamps, flowing or stagnant bodies of water with flat shores, nor upon moorland, as well as impervious ground (clay or loam soil). The vicinity of bodies of water would also cause the stable buildings frequently to be surrounded by fog (in the evenings), in which case the walls would absorb the moisture.

If it is impossible to select a sufficiently dry building site, then the site must be drained. When draining the stable ground a drain line is generally located at a distance of about 4 meters (4½ yards) from the outer wall and parallel with it, and about half a meter lower than the foundation extends. Another drain line is laid at the same depth along the stable surface. The drain lines should be given a fall of at least 3.5 centimeters to every 10 meters (1⅜ inches in 10 yards). In addition to this an outlet should be provided for the drain water. Furthermore, an attempt should be made to keep the foundation dry by diverting the rain water as it falls off the roof and walls. A plastered or concrete gutter of

about 1 meter in width, sloping slightly away from the stable, built entirely around the building, is very efficacious for this purpose.

The direction in which the front of the stable faces and of the side on which the doors and windows are built has an influence upon the lighting and supply of air as well as upon the natural temperature of the stable. With regard to these points it is essential that the stable be protected against storms, be warm in winter and cool in summer, and that the animals should not be troubled any more than can be helped by too bright a light or by drafts and insects. Usually it is preferable to have the stable face toward the east, sheep stables toward the south or west (if in those particular places no very rough east or west storms prevail). The north side is usually avoided, as it shuts out the direct rays of the sun and often permits cold and damp stalls; but on the other hand it offers the advantage that during the summer the annoyance from flies is least on this side. For hog pens the southern exposure is best, especially then when the animals are also kept out in the open at night during the summer. On the other hand, stables for work, milk and fattening animals that have their main frontage toward the south or west are not suitable, as such frontage produces a hot stable for the summer as well as a greater annoyance for the animals from flies. In case of necessity the disadvantages of a southern exposure can be lessened by planting trees at some distance to give protection against the burning midday sun. It is of economic importance to see to it that the main frontage, namely the entrance to the stables, can easily be watched over from the dwelling house.

II. The Foundation and Outer Walls

The *foundation* is supposed to make the floor of the stable waterproof. Otherwise the ground water penetrates from below and from the sides into the pourous building materials and then rises, becomes of capillary attraction, thus causing dampness in the stalls as well as in the cellar below. To keep out the water, building materials should be chosen for the foundation that are as little porous as possible (granite, basalt, well-burnt bricks, rammed concrete, etc.) and that are well joined. Besides this a layer of tar or asphalt 1 centimeter (3/8 inch) in thickness, glazed clinkers set in cement, etc., are placed upon the so-called leveling layer of the foundation at a height of about 15 to 30 centimeters (6 inches to 1 foot) above the ground. The sides of the foundation should then be covered with asphalt, tar, etc., to prevent dampness from penetrating from the sides. The foundation is only occasionally surrounded by a strong outer wall (12 centimeters—4½ inches—in thickness) which is made of bricks set in cement, uncovered on top and 10 to 15 centimeters (4 to 6 inches) distant from the foundation.

With regard to the *outer walls* of the building, great emphasis has hitherto been laid upon their porosity. This quality determines their permeability for air (poor ventilation). That air can enter through por-

ous materials has been proved by the familiar experiment of having a light blown out by the air passing through a brick.[1] It might appear as though this experiment proves that a considerable part of the ventilation takes place through the walls. This, however, is not true, for the atmospheric pressure resulting from exhaling is greater than the wind pressure.[2] With accurate tests it has been determined that with a wind pressure of 1 kilogram to the square meter (2 pounds to the square yard), depending upon the material,[3] only 5 to 10 liters (quarts) of air entered in 1 hour through 1 square meter of wall surface; for stable space with 14 square meters frontage and with a medium wind of 3 kilograms pressure, the amount of air admitted hourly is 0.2 to 2.0 cubic meters, while the hourly requirement of air for 6 cows averages as high as 300 cubic meters. According to this the pore ventilation is so negligible with a moderate wind which does not strike the wall perpendicularly that it is scarcely to be considered. A volume of air that would be worth mentioning would enter only with severe winds that strike the wall directly, in which case the aperatures for ventilation, the accidental cracks of doors and windows, allow more than the desired change of air. The importance of pore ventilation used to be greatly overestimated; today we know that it is practically insignificant. But because of this the porosity of the walls has not lessened in value, for it is the porosity that essentially influences the heat conduction of the walls. This should be low, so as to make the stable temperature during summer and winter as independent as possible of the outside temperature, and also to avoid as much as possible during the cooler times of the year a condensation of the water vapor of the stable air, which is usually damp. A wall made of material that conducts heat poorly can be warmed and kept warm more easily during the winter on the inner surface (stable side) than a wall made of material that has good conduction of heat. The air that comes in contact with it is cooled off less, and therefore, consuming the same content in moisture, causes less (or no) dampness on the wall through condensation of water vapor than if the wall were constructed of good heat conductors.

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[1]Fasten a glass tube with putty or cement to the middle of one of the broad sides of a brick (tile), and on the opposite side a funnel whose tip is fairly small. The remainder of the brick is coated with oil, paint or tar. By blowing hard into the glass tube a burning taper held in front of the tip of the funnel can be extinguished through the brick.

[2]By blowing a pressure of 10 to 20 centimeters mercury = 1,300-2,600 kilograms on 1 square meter surface can easily be exerted. On the other hand the pressure of a moderate wind amounts only to 1 to 5 kilograms, of a strong wind 20 kilograms, and of a storm always at least 100 kilograms to 1 square meter.

[3]Clay brick is the most porous, then in decreasing porousness tufaceous limestone, pine wood (cross cut), air mortar (lime mortar), lighty baked bricks, unglazed clinkers, Portland cement, green sandstone, oak (cross cut), gypsum (molded), glazed clinkers (vitrified brick). According to Maercker, 1 square meter of wall surface area allows the following amount of air to pass through the designated stones in 1 hour:

Sandstone	1.7 cubic meters of air
Quarry limestone	2.3 cubic meters of air
Bricks (tile)	2.8 cubic meters of air
Tufaceous limestone	3.6 cubic meters of air
Clay brick	5.1 cubic meters of air

The porosity of the walls is greatly affected by the painting or dressing given them. A coat of whitewash, still better a coat of oil paint, or still better a layer of Dutch tile, lessens the porosity, which is above all essentially affected by the dampness. For this reason simply a dampening of the wall lessens its perviousness to air 15 to 90 per cent, according to the fineness of the pores.

The heat conduction is great with dense materials (metal, massive stones); with porous materials that contain air (tufaceous limestone and especially wood) it is very slight. As it is known that air is a very poor conductor of heat, special air spaces are sometimes built into the walls; so-called hollow walls are constructed (Fig. 167). According to recent investigations, however, these lower the heat conduction but very little; in fact "sweat water" is much more apt to collect in these cavities, thus dampening the walls. It is more expedient to fill the air spaces of such a wall with *Kieselguhr* (diatomaceous earth), shavings, excelsior or sand. The porous material furthermore possesses a lower admissibility of heat; it can be heated by a small amount of heat, which is of course advantageous.

Formerly the walls of stables were expected to possess to quite a degree the power of absorbing water. The rather erroneous assumption was followed that water that was precipitated inside was absorbed by the wall and then gradually evaporated off to the outside. If the walls are constructed of poor heat conductors then a condensation of water should not result on the inner wall surface. This occurs only in hot, steamy stables. The dripping of the walls is best avoided by suitable ventilation. Material that has great power of absorption has on the contrary the disadvantage of allowing atmospheric precipitations (rain, etc.), if beaten against the wall by the wind, to penetrate far into them, and then to consume much heat during their evaporation, therefore cool off the wall, and in this way cause the condensation of water vapor on the inner surface of the wall.

The outer wall therefore requires a material that can retain air because of the poorer heat conduction and lessened heat absorption, but it need not be pervious to air and water. It is even better to destroy the porosity, and, after drying out the walls, to cover them on the inside and outside with a nonporous layer. To protect the outside against penetrating dampness, it is advisable to rough cast the outside surface with impervious material (glazed clinkers) or to give it a covering of shingles, slate, roof tiles, or a coat of gypsum and water-glass or of oil paint. The inner walls can be cleaned and disinfected so much more easily if given a coat of oil paint, cement plastering, or a layer of tile, the latter two no higher than 1.5 to 2 meters (5 to 6½ feet). In hog stables the cement plaster should be entirely avoided. On the other hand, the cement plaster is required by (German) veterinary police authorities in the stables of hotels and dealers. Here it is usually 1.5 meters in height, except along the manger wall, where it is 2.5 meters.

The building laws prescribe a certain thickness of walls. The thickness of the wall must be considered here, since very thick, massive walls are of course more difficult to heat. The heating of the inner surface of a thick wall can be easily accomplished if the inside wall is covered by a layer of particularly porous bricks and if possible has an adjoining (to-

ward the outside) hollow space filled in with porous material. This is especially advisable for stables for horses that are out at work during the day. For stables that are constantly occupied by milk cows and cattle intended for fattening this is not necessary. Thick walls have, on the other hand, the advantage that they conduct the heat less easily than thin ones. A stable with thick walls that is occupied constantly is generally warm in the winter and cool in the summer. The heat enters the wall very slowly and at a constant loss. The outer surface of a wall may be heated during the summer to 40-50° C. (104-122° F.) by the rays of the sun. The inner surface of a wall 15 centimeters (6 inches) in thickness will after about 5 hours reach a maximum temperature of about 30° C. (86° F.); with a wall 50 centimeters (20 inches) in thickness only about 24° C. (75.2° F.) after approximately 10 hours. By allowing the walls to become overgrown with vines, etc., the heat of the sun is materially lessened. The thickness of the wall should not be less than 38 centimeters (15 inches) if the stable temperature is to be kept at the desired degree.

Porous bricks are especially desirable as building material for stables. Quarry stone is a better conductor of heat; it also possess greater power of heat absorption, and during the winter become covered more easily with moisture, especially when the animals that stand facing the wall constantly breathe against it. Walls built of clay paneling, which can still be found frequently in certain districts of Germany, are not sufficiently resistant for horses and hogs, which often lick, bite and paw at the walls. An attempt is sometimes made to overcome this nuisance by covering the wall with a coating of cement as high up as the animals can reach. In cattle and sheep stables the framework is given a foundation at least as high as the accumulated manure would reach. The least care need be exercised with the choice of building material for sheep stables. Moldiness of the walls is to be less feared here than with other stables. During recent times the loam or clay wall that has been used for centuries has in a measure come into its own through the curable, resistant clay-wire wall of Paetz.

When constructing this new clay-wire wall, which is not well known but which is to be recommended, tamping boxes 42 centimeters (16½ inches) in height are erected, which are held together with iron clamps above and bolts below. Into these tamping cases a galvanized hexagonal Paetz wire netting is bent in at right angles, which completely surrounds the loam mass 30 centimeters (1 foot) in height that is to be tamped in. The network is fastened to the base of the masonry by a cement seam, 10 centimeters (4 inches) in thickness, which completely surrounds the net with cement. After this three to four layers of loam, clay or potter's clay are pressed in fairly dry; the ends of the wire netting, which at first bent backward, are bent into the walls and fastened with wire. The tamping case is raised higher, a new wire netting is put in and fastened to the base with a layer of concrete cement 2 centimeters (⅞ inch) in thickness, and then as described above the second layer of loam, etc., is tamped in. The corners, windows, door frames, and the supporting pillars placed at intervals of 5 or 6 meters, are all constructed of concrete cement. The wire netting is freed on the outside of the particles of loam and given a coating of lime mortar. The Paetz walls are three times cheaper than brick

walls, excellent heat retainers, fireproof, and after weight tests by the Royal Board for Testing Materials in the principality of Lichterfelds were found just as satisfactory for all agricultural buildings as those built of brick and with walls of the same thickness.

With walls of wooden framework all seams and cracks should be avoided and the inner surfaces of the walls should be planed smooth in the interest of cleanliness. To make disinfection possible they are at times given a coat of cement. This, however, makes the wall cold in winter, and condensed water vapor easily accumulates on it.

In recent times breeders of pigs have in many instances returned to the old pig stalls made of wood with a clay covering and straw roof, which have the advantage of cheapness over the modern pig pens. Furthermore, they are always dry during the colder time of year, and as a result of abundant natural airing are always well ventilated. On the whole the pigs are healthier in them. They have the great disadvantage, however, that they can not be disinfected. Furthermore, these huts are small, and on larger hog farms many such huts would be necessary, which would make supervision and attendance very difficult.

The walls should be dry. Wet walls favor the maintenance and proliferation of disease and putrefactive bacteria as well as of mold and fungi whose products of metabolism mingle with the air. This can give the air an unpleasant, damp, moldy odor. Besides this contamination of the air, there are also spores scattered about. Wet walls, moreover, are cold and may lead to illness resulting from the chilling of animals leaning or lying against the walls. Catarrh of the respiratory tract, rheumatism and intestinal catarrh often appear in such stables, and the spread of specific infectious diseases, such as tuberculosis, strangles, etc., is facilitated. Often enough the nutritive condition is impaired, serviceability is lowered, chlorotic conditions (among sheep) arise, and a low state of thriftiness of calves and young pigs, etc., prevails. In the wood (ceiling and beams, etc.) of damp stables dry rot (*Merulius lacrimans*) often establishes itself, and its rapid proliferation through the wood soon causes the woodwork to decay. This has no particular hygienic significance. To prevent it a coat of carbolineum (creosote oil), or, better still, zinc chlorid, is recommended.

The following may be considered as causes of damp walls:

1. Incomplete drying out of newly built stables.[4] Dryness is usually tested by the sense of sight and smell, and the stable is considered ready for occupancy when no moldy smell or wet spots on the walls are in evi-

[4]In the construction of walls large quantities of water are used. To make the binding material hold, the stones are dampened; bricks are usually dipped into water; dressed stones are generously sprinkled with water. The mortar, which consists of 1 part of slaked lime and 2 or 3 parts of sand, contains large quantities of mechanically mixed and chemically combined water (as hydroxid). These large quantities of water must first be given up again before the building is fit for occupancy. To help the drying out, the rough masonry should not be given the finishing coat until it has dried out. The drying out of both the rough and finished masonry takes place rapidly enough during warm, dry weather under the influence of the open air. During unfavorable weather conditions the time needed for drying out may be shortened by burning coke in stoves near open windows. The time required for drying out is usually estimated at 6 to 10 weeks.

dence. This is, of course, not an entirely unobjectionable method of procedure.[5]

2. The absorption of dampness from the ground. This occurs when the foundation has not been made sufficiently impervious to such dampness and the stable walls have not been made to fit closely enough to the foundation. This disadvantage can be improved by draining the floor and by erecting an outer wall.

3. Dampness caused by beating rain, namely, when the outside surface of the walls consists of porous, absorbent material. If the water evaporates it will cool off and in this way again form water vapor on the inner surfaces, which may easily result in constantly damp walls. This can be remedied by constructing isolating layers or by covering with im-

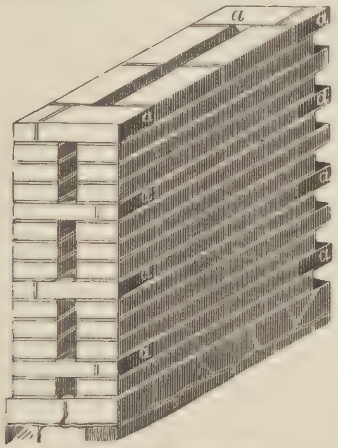

Fig. 167. Hollow wall.

pervious materials that at the same time also check the cooling off as mentioned on page 263, or by simply extending the roof at least 60 centimeters (2 feet) farther out and attaching a gutter.

4. The occurrence in the walls of salts (calcium nitrate—wall saltpeter—and calcium chlorid) that attract water. If the surrounding air is dry these walls will give up their dampness again. They will be dry, then wet, according to the humidity of the air. As a result of this constant change, the plaster begins to crumble more and more; later the masonry (walls) also, and then the structure falls into ruin. For this crumbling of the walls there is no other permanent remedy than to replace the masonry containing salts that attract water with new masonry. The hygroscopic salts that have been mentioned can get into the masonry when water that contains these salts is used n the construction. More frequently, however, they do not accumulate on nor enter into the stable walls until later. In this case they originate in the ammonia, which is

[5]Objectively the dampness of the mortar can be determined as follows: Mortar tests of the plaster and joints are made on the shady and weather side, the water contents of which should be accurately determined (page 85). It should not amount to more than 2 per cent.

evident in abundance, especially in poorly ventilated horse stables. The ammonia precipitates on the wall with the water condensed from the air, if it has not indeed been splattered against the wall with the urine. Through the activity of bacteria the ammonia is oxidized into nitric acid, which combines with the potassium hydroxid and lime, forming potassium nitrate and wall saltpeter (calcium nitrate). This wall saltpeter produces, as has been mentioned, the crumbling of the walls, and can also act injuriously if it is licked off by the animals, causing inflammation of the stomach, intestines and kidneys of calves, foals and lambs, even causing fatal results. The best preventive against the formation of wall saltpeter is proper ventilation and cleanliness, which are also urgently advised for other reasons. To remedy the existing evil the wall should be protected by cement plaster or a brick wall, or should be lined with boards. The latter only prevents the animals from consuming the wall saltpeter. For this purpose it is often advised that muzzles woven of willow be put on the calves after feeding time, which prevents them from eating stable manure and urine-soaked litter.

Once or twice a year the walls should be whitewashed, or (in case of being coated with oil paint or faced with Dutch tiles) washed off. This is advised not only for reasons of cleanliness but also to remove scattered disease germs and to lessen the annoyance of flies.

III. Dimensions

The size of the stable is determined by the number of animals that are to occupy it, size of stalls, width of feed alley, and width of manure passage, liquid manure gutter and cribs.

For working horses a stall 3 meters (3 yards 10 inches) in length is allowed, with separating swinging poles 1.3 to 1.7 meters (4 feet 3 inches to 5 feet 7 inches) apart, with box stalls 1.8 to 2.2 meters (5 feet 11 inches to 7 feet 3 inches) in width; for fancy and cavalry horses, 3 to 3.4 by 1.6 to 1.8 meters (9 feet 10 inches to 11 feet by 5 feet 3 to 10 inches); for stallions, for large draft horses and with box stalls for fancy horses, 3.5 to 4.5 by 2 to 2.5 meters (11 feet 5 inches to 14 feet 9 inches by 6 feet 6 inches to 8 feet 2 inches). The crib is arranged according to these lengthwise measurements. The stable alley is arranged 1.8 meters (5 feet 10 inches) in width where there is but a single row of stalls, 2.8 meters (9 feet 2 inches) with a double row; in stables of fancy horses an extra 0.5 to 1 meter (19 inches to 3 feet 3 inches) is allowed for each. The size of a horse box stall should be 3 to 3.5 meters (10 to 11½ feet) square; if several foals are to occupy one stall then 5 square meters (5½ square yards) should be allowed for each animal.

A medium sized cow is given a stanchion of 2.5 by 1.2 meters (8 by 4 feet); large cows, bulls and draft oxen, 2.8 to 3 by 1.5 feters (9 feet to 9 feet 10 inches by 5 feet); small cows and young stock, 2 to 2.5 by 0.8 to 1.1 meters (6 feet 6 inches to 8 feet 2 inches by 2 feet 7 inches

to 3 feet 7 inches). The Dutch stable arrangement, which with justice is constantly gaining more adherents and is of great importance in producing clean milk, allows the cows a stall space of only 1.6 to 1.8 meters (5 feet 3 to 11 inches) in length, behind which runs a gutter 50 centimeters (20 inches) in width and about 40 centimeters (16 inches) in depth (Fig. 190). With these short stanchions the cribs must be kept low (35 centimeters—14 inches— in height; see page 296). Young cattle, if a larger number are to occupy the stalls, need an area of 4 square meters (43 square feet); calves up to 12 weeks require 2 to 2.5 square meters (22 to 27 square feet). These dimensions are estimated without

Fig. 168. Interior of horse stable. (After Kasper Berg, Nurenberg.)

including the crib or liquid manure gutter. The feeding alley, as well as the manure alley, including the liquid manure gutter, should be kept 1.35 to 1.5 meters (4 feet 5 inches to 5 feet) wide, with the single row stabling plan, or at 2 to 2.5 meters (6 feet 6 inches to 8 feet 2 inches) for the double row.

Sheep should be given at least 1 to 1.2 square meters (10¾ to 13 square feet) floor space per head, including the space for cribs and racks.

Sows that are either pregnant or have suckling pigs, as well as boars kept for breeding purposes, need pens of 4, 5 or 6 square meters (43 to 65 square feet) in area. Frequently stables for hogs are arranged so that one pig pen lies between two pens for mother sows. The pen for

the young pigs is connected with the other two pens by means of loopholes for the young pigs. If a number of animals are lodged in one pen then 0.5 to 0.6 square meter (5 to 6½ square feet) area is allowed for each young pig, 0.8 to 1 square meter (8½ to 11 square feet) each for animals up to one year, 1 to 1.3 square meters (11 to 14 square feet) up to two years, and for hogs intended for fattening 1.6 to 2.8 square meters (17 to 30 square feet) each. The passage between the pig pens should be 1.25 to 1.6 meters (4 feet to 5 feet 3 inches) wide.

On smaller farms the stalls for cattle and hogs are in the same room; on larger farms they are usually entirely separated. With a large stock of animals it is advisable to avoid stabling all animals of one kind in one common space. Often at the expense of the overseeing, an effort is made to prevent the spread of animal diseases by stabling the animals in separate rooms which are separated from one another by strong partitions and which must have special doors for the time being. From a sanitary point of view such a plan of separation is well worth recommending, but if it is to fulfill its purpose it must be carried out as thoroughly as possible. Doors should either not be broken through the partition walls at all, or, if they are built in, they should usually be kept tightly closed. No intercourse should occur between the separate divisions. Each division should be looked after by a special stable personnel; each division of the stable should have its own utensils. Separation of the entire stock of one kind of animal is practiced most frequently with horses. For cattle and hogs this system can receive nothing but commendation. The separate sections for cattle should be of such a size as to accommodate about 50 to 60, at the most 70 to 80 head. To make the stable accommodate a larger number of cattle is opposed to good economics. The military garrison building regulations order that within the military stable buildings separations should be so arranged with sliding doors that not more than about 50 horses stand in one division.

Besides this, it is advisable to construct a special small stable room which is partitioned off by a wall and provided with a special entrance from without; this is to be used in an emergency, especially in case of disease, as a hospital as well as for isolating animals that have just been bought.

The height of the stable should be adapted to the size of the stable and to the number of animals. Stables that are too high easily become too cold in winter, while those that are too low are generally damp and too warm.

For cattle and horse stables that accommodate up to 12 head a stable height of 2.5 meters (8 feet) is recommended; for those with 12 to 30 head, 3 meters (10 feet), and for those with over 30 head over 3 meters in height. For sheep, stables should generally be a height of 3 meters. If the stables are to accommodate over 300 sheep the height

should be increased to 4 meters (13 feet). Pig sties are built 2.5 to 3 meters (8 to 10 feet) in height, unless it is a matter of a single sty, for which a height of 1.5 to 1.7 meters (5 to 5½ feet) suffices.

The measurements for stalls, height of stable, etc., should be reckoned so that each animal has a sufficiently large air space, 20 to 30 cubic meters to 500 kilogram of live weight (about 20 to 30 cubic yards per 1,000 pounds live weight). In certified milk dairies, the designated dimensions are sometimes greatly exceeded and the stable corresponds in size to an allowance of 30 to 70 cubic meters (33 to 77 cubic yards) of atmosphere for each full-grown cow.

If in larger barns pillars are necessary for the support of the roof, they should be round and smooth (Fig. 168) so as to prevent injury to the animals as much as possible, or they should at least have the corners and edges rounded off. The pillars should not be painted with red lead if the animals can lick them; otherwise lead poisoning will frequently result.

IV. Ceiling and Roof

The ceiling should keep the stable warm, should remain warm itself, and should in general be tight enough so that the space above can be used for storing feed or even for living quarters, so that neither the

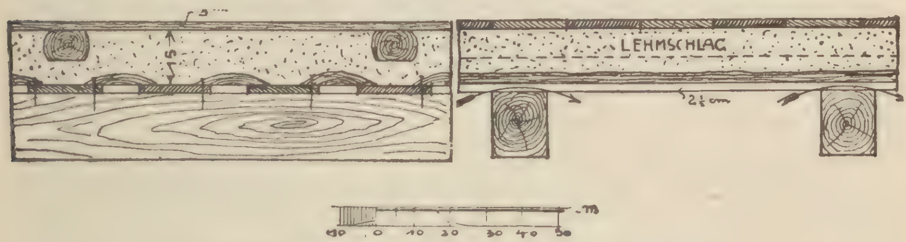

Fig. 169. Wooden plank ceiling, according to Jummerspach.

stable odors can penetrate upward nor dust, etc., fall through from the rooms above down into the stable. It is inadvisable to have an opening in the ceiling that will connect the stable directly with the hay loft, for the trap door can not close tightly enough to prevent the stable odors from penetrating into the hay loft. If the opening, however, first leads into a hall that is aired and partitioned off sufficiently, but which will not serve for storing feed supplies, no sanitary scruples can be raised against it.

The ceilings are either built solid or beamed. Beamed ceilings are constructed as follows: Boards are fitted in between the beams of the ceiling and then usually covered with a layer of straw and clay. Or poles or small boards of the required length are wrapped about with straw which has previously been coated with clay. After the clay has partly dried the boards are covered with laths. The ceiling is then coated above and below with clay and then whitewashed.

The wooden ceilings have the disadvantage in comparison with those built of stone or brick of possessing less density, less durability and of being less safe in case of fire, but on the other hand have the advantage of helping natural ventilation considerably. They are best suited for sheep stables and small isolated pig sties, and less desirable for horses.

Solid (masonry) ceilings are greatly to be preferred for cattle and larger pig sties, as wooden ceilings are not sufficiently impervious to the water vapor which appears abundantly in these stables, although the perviousness of wooden ceilings can be lessened considerably by nailing on tar paper. The solid ceilings should be constructed of material that contains much air but can readily be made impervious to air and water by giving it a coat of oil. Formerly the solid ceilings were built of brick, in which case it sometimes happened that the ceiling became so covered with moisture during the colder times of the year that the water dripped down and annoyed the animals and stable help. This disadvantage can be remedied by the construction of an especially adapted ceiling, by good ventilation, and by protecting the ceiling of the stable against a severe cooling off by placing layers of hay, straw, and other poor conductors of heat over it. During more recent times the use of bricks has frequently been replaced by artificial stones, by insulated cement ceilings with grooved paper boards, etc. They are still poorer conductors of heat and have the disadvantages of the brick ceilings to a lesser degree.

If there is no floor above the stable a special roof separated by an air space is built over the ceiling, frequently constructed of wood and cement filled up with earth. However, the space between the stable ceiling and roof is generally used for a hay loft, etc.

The thatched roofs and shingle roofs that were used so much in olden times are dangerous in case of fire and are, therefore, not to be recommended.

The tile roofs are usually good if the tiles have been well laid in lime, but have the disadvantage of easily becoming covered on the inside with hoar frost during severely cold weather, which after thawing drips down on the feed stored below and thus causes it to spoil. This evil can be avoided easily by constructing a special lining of boards.

Slate roofs allow the rain and snow to penetrate, especially during severe winds, unless they are placed on tar paper or on some other impervious foundation.

The roof should project a suitable distance to protect the outer wall against the action of the sun and rain. Gutters are necessary to carry off the rain water.

V. Windows, Lighting and Doors

The windows serve to let in air as well as light. From a sanitary point of view plenty of light is absolutely necessary for the cleanliness of a stable, which depends on the lighting. Light is furthermore the

most important, natural disinfectant. Excreted disease germs are weakened and finally killed by diffused daylight. The disinfecting action of light must, on the other hand, not be overestimated. It possesses very little power to act at any depth. Therefore even in a well-lighted stable the utmost cleanliness and the prompt removal of all refuse and excrement should be observed. Light also has a great influence upon the well-being of the animals and exercises an important influence upon metabolism by affecting the amount and condition of the blood.

The stables should be light, at least half as light as human dwellings. This degree of lightness is accomplished if the total area of the windows equals one-fifteenth to one-twentieth (in human dwellings one-tenth) of the floor area. In horse stables one window of 1.50 to 1.75 square meters (1 2/3 to 2 square yards) of lighting area is usually allowed for three stalls (Fig. 168). Dark stables may be made lighter by painting

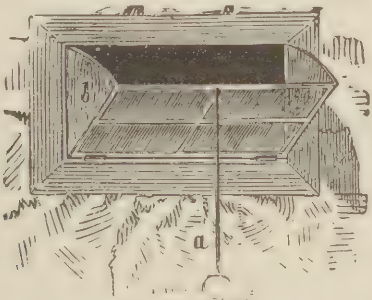

Fig. 170. Tilting window. *a*, **Regulating device;** *b*, **side pieces.**

the walls a light color. The foregoing rule should hold true except in the case of stables for animals that are to be fattened. Since animals that are being fattened are no longer used for breeding purposes, and moreover have only a short time longer to live, and the fattening makes better progress in the dark than in the light, good lighting can most readily be omitted with these animals.

Care should be exercised in the distribution of the windows so that the animals that are tied to their places (horses) are not annoyed by glaring, direct sunlight, which may cause injury to the sight. This has also been known to occur among horses with continuous one-sided lighting, which results easily from the so-called deep or diagonal window arrangement. This disadvantage can be most easily overcome by arranging the animals in a single row stabled lengthwise and by constructing windows in the walls at the rear of the animals. With the double stabling the windows should be kept high enough (2.50 meters—2¾ yards) above the floor so that the light falls over the heads of the animals into the stable (Fig. 168). The intense light can furthermore be dimmed by means of frosted glass or by a coat of lime or by means of shutters, venetian blinds, etc.

The windows furthermore aid in ventilation. Windows with wooden frames are not satisfactory because of their tendency to warp. It is better to have iron frames, which should, however, be protected against rusting by painting them. Windows especially adapted for ventilation are the iron "tilting" windows, either open or closed. They are provided with a horizontal pin at the lower edge to which side pieces of tin are attached so that the cold air can not blow directly upon the animals standing below. By setting the window at an angle the current of air is deflected upward. This cools off the ceiling of the stable to such an extent that the water vapor of the stable air collects on the ceiling and then drips down upon the animals. The "tilting" windows that turn from the middle have the disadvantage of letting the cold air pour directly down upon the animals standing beneath.

For artificial lighting all lighting arrangements in use may be considered for animals. With the use of kerosene lamps care should be exercised that the air is not polluted by allowing the lamp to smoke or smolder. All ordinary rules of precaution should of course be followed in the lighting of stables. Private stables are usually lighted up at night. In the army the stables are dimly lighted during the night because the supervision makes this necessary.

The *doors* should be so arranged that all possible drafts should be avoided when they are in use. Drafts often occur in a most annoying way if the doors on opposite walls lead directly to the outside. This can be avoided by screens and halls. The number of doors depends on the size of the barn. One door is estimated for not more than 75 head of large stock.

The doors must close tightly enough, must open toward the outside (in case of fire), should be arranged so that when open they can be fastened to hooks on the wall, and constructed so that any injury to the animals can be avoided. For this reason all large projections, as, for instance, long latches, hooks, etc., should be avoided. The latches or door knobs are usually fitted into the doors (Fig. 171). To separate a door into a lower and an upper wing, as is frequently done in northern Germany, has the advantage of allowing ample ventilation through the upper door while the locked lower door prevents animals that have broken loose from getting out. Dividing a door into an upper and a lower wing also has its disadvantage, since doors that are thus divided do not close properly. Sometimes lattice doors or bars placed horizontally or iron rails are put up in addition to the doors to serve the same purpose as the divided doors.

The doorposts should be rounded off or at least have their sharp edges removed. It is advisable to insert rollers 15 centimeters (6 inches) in diameter and 2 meters (6 feet 6 inches) in length that turn easily and are placed vertically along the doorposts of foal stables. Sometimes the rollers are set into the doorframe about halfway. They are supposed

to prevent the animals from bumping their hips (even breaking off the outer corner of the ilium) in crowding through the door, or to avoid other injuries. Such rollers, 1 meter (yard) in height, are also installed in sheep stables to protect the fleece and mother animals that are well advanced in pregnancy.

The doorsills should if possible be made level with the floor in order to avoid stumbling. Toward the outside they are allowed to project about 4 to 8 centimeters (1½ to 3 inches) above the slightly sloping landing that leads to the door so that rain water will not flow into the stable.

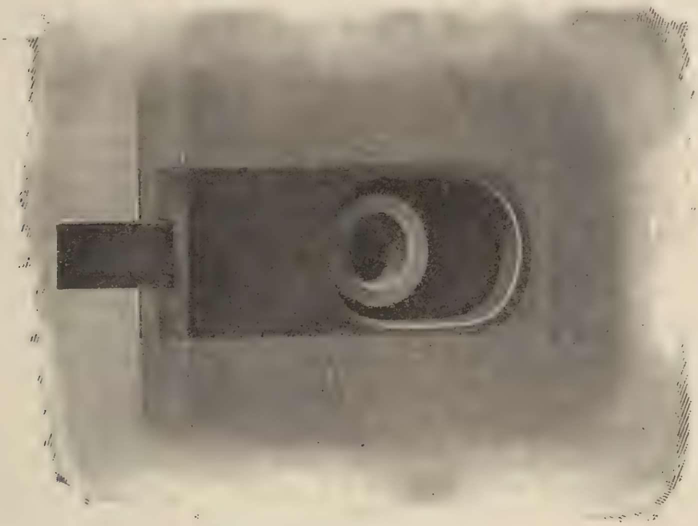

Fig. 171. Door latch.

VI. Ventilation

The presence of animals in a closed space gradually pollutes the air. This pollution is due to the following causes: (1) The consumption of the oxygen by the animals as well as by the microorganisms that occur in great numbers in the manure, etc., and by the kerosene lamps sometimes used for lighting purposes. (2) The giving off of gaseous impurities by the animals and other agents mentioned above, as, for example, carbonic acid and foul-smelling gases (intestinal gases, sweat, ammonia and other decomposing agents of organic substances, products of incomplete combustion of the illuminating substances, etc.). (3) The giving off of large quantities of water vapor by the animals and also by hot mashes, warm soups, drinks, etc., which mix with stable air. (4) The production of heat by the animals, which is sometimes given off in such quantities that the loss of body heat is sufficient to produce serious

results, and that diseased conditions similar to heat stroke result. (5) The creation of dust in the stable when feeding dry, coarse feed, when sweeping, cleaning, etc., and of worse admixtures of bacteria and fungi to the stable air that is usually already overcharged with germs. Although the stable air contains about 50 bacteria and 7 spores of molds or fungi to one liter of air under favorable sanitary conditions, the number of bacteria increases to 400-700 and that of the fungi from 100-250 (Cinotti) under unfavorable conditions. Spissa even found over 5,000 bacteria in one liter of air in a filthy, poorly ventilated stable in Italy. (6) If sources of infection exist in the stable, disease germs are added to the dust of the air. The first of such sources of disease to be considered are the sick animals, those that are afflicted with diseases of the respiratory passages, such as tuberculosis, glanders, swine plague, foot-and-mouth disease, contagious pleuropneumonia, rinderpest, etc., and that expel infected droplets, or that give off the infective substance from the skin in the form of small, dry scales and particles of dust (smallpox, wound secretion, etc.). The disease germs are usually given off in a moist condition and dry up later on. This, however, is usually a slow process, because of the very damp air that generally exists in the stable. The dried infectious substance can be reduced to dust by the traffic passing over it, by sweeping, etc., and thus again be admixed with the air. Disease bacteria must of course necessarily be able to endure this desiccation if they are to remain infectious, as is the case, for example, with tuberculosis bacilli, streptococci, etc.

If animals remain for a long period of time in polluted stable air their health may be seriously affected. Under certain conditions the nourishment, the formation of blood and the power of resistance may be injured. If sources of infection are present, the disease bacteria will accumulate in greater numbers with insufficient ventilation, and the infectious diseases (tuberculosis, swine plague, contagious pleuropneumonia, glanders, pectoral influenza, strangles, etc.) will spread more rapidly and will frequently result in a more virulent form than in stables with good air. Stable air that contains much dust (stable and hay dust) irritates the respiratory organs and creates places of entrance for infection resulting from inhalation (tuberculosis), as the tests of Duerst with guinea-pigs prove.

On the other hand, observations have been made that the disease and death rate among animals decreases and the efficiency is increased with the installation of a good ventilation system. With regard to this Stockmayer informs us that in a model cow stable in Frankfort-on-the-Main 80 well-fed Swiss cows yielded an average of 400 liters of milk per year more after the installation of a good system of ventilation with absolutely the same feeding than before. Schade observed that after repeated, thorough whitewashing with milk of lime and ventilation of a dark stable that had formerly been poorly ventilated, six cows gave a daily

increase of 1½ to 2 liters in the yield of milk. The quality of the milk is also affected by the purity of the air. It is, therefore, important that in case the air is not constantly replenished sufficiently it should not be done just at milking time, but at least half an hour before the milking is begun.

The polluted air should, of course, be replaced by fresh, pure air. The quantity of fresh air needed should first be ascertained, then the ways and means by which the required supply can be furnished can be determined.

1. Fresh Air Requirements

The carbonic acid gas must be considered in determining the need of ventilation. The highest carbonic acid content of stable air that can just barely pass as still good has been accepted at 2 to 3 per cent, based upon von Maercker's experiment stable air containing more than 3 per cent CO_2 is as a rule polluted, and 4 per cent must be considered as the extreme limit that can be set. In judging stable air with the ordinary senses, a higher content in carbonic acid, even 8 to 10 per cent can not be recognized as such. On the other hand the temperature and humidity of the air exercise a great influence upon the subjective perceptions, and a warm, vaporous air will appear to be polluted even with a low content of carbonic acid. The stable air possesses the same composition at different atmospheric levels, namely, the same content of carbonic acid. The opinion that is occasionally expressed that the air near the floor is richer in carbonic acid than that near the ceiling is therefore false. The carbonic acid content of the stable air should constantly be kept at 3 per cent, if possible lower, by means of ventilation.

The carbonic acid that is given off hourly amounts to about 300 cubic centimeters per 1 kilogram of live weight among the farm animals. The following table gives a more exact insight into the exchange of gas of our domestic animals while at rest.

Animal	Exchange of gas for 1 kilogram live weight for 1 hour — Consumption of Oxygen	Liberation of CO_2
	cc.	cc.
Horse	235	241
Cow	328	320
Sheep	343	341
Hog	392	336

These figures are, of course, greatly affected by the feeding, by the surrounding temperature, etc. The figures noted should only be taken as an average.

Of the materials used for illuminating purposes, a burning stearin candle liberates per hour about 12 liter of CO_2, a kerosene lamp liberates 60 liters, and a gas flame 100 liters.

If we assume in the following example that we are dealing with stable space that accommodates ten cows of an average live weight of 400 kilograms each, these cows would produce a total hourly liberation of $400 \times 10 \times 300$ cc. = 1,200,000 cc. CO_2. As one liter of fresh air, brought in through ventilation, may already contain 0.3 cc. of CO_2, and 1 liter of stable air may contain up to 3 per cent = 3 cc. of CO_2, then every liter of air that is brought in can still absorb 2.7 cc. of CO_2 before reaching the highest permissible content of carbonic acid. If 2.7 cc. of CO_2 require 1 liter of fresh air for dilution, then

1,200,000 cc. CO_2 require 1,200,000:2.7 = 444,444 liters or 444.4 cubic meters of fresh air for this same purpose.

At least 444.4 cubic meters of air must, therefore, be brought hourly into the stable space in which ten cows are stabled. Since the other sources of carbonic acid besides the cows (microorganisms, material used for illuminating purposes) have not been considered in arriving at this figure, the supply of fresh air must be reckoned decidedly higher, i. e., a total of 45 to 70 cubic meters per hour per head (500 kilograms live weight) of large stock, and 45 to 70 cubic meters per 500 kilograms for small stock. Since stable air can not be renewed hourly more than two or three times with the aid of the usual methods of ventilation, the result is that the smallest air space for a cow must be fixed at about 20 to 30 cubic meters (22 to 33 cubic yards), i. e., one-half to one-third of the amount of air that is added hourly. If the air supplied through ventilation is less than designated, which is generally the case, the volume of air per head must accordingly be estimated higher.

2. Natural Ventilation

Ventilation takes place to a certain extent, without our assistance, through the pores of the walls, of the ceiling and of the floor, as well as through the grooves and cracks of the doors and windows. This ventilation is called natural ventilation. It is in contrast with the artificial ventilation which is accomplished by special devices.

The impelling forces of natural ventilation are variations in temperature, air currents and diffusion. Pore ventilation is so very insignificant under ordinary circumstances and with tight ceilings that it is hardly worth considering. It has the same disadvantage that exists with the ventilation through accidental cracks and grooves, namely, that it cannot have an arbitrary regulation. During a calm or slight stirring of the air it is entirely insufficient, while during storms it at times becomes an annoyance. The source of the air flowing in is often unknown with natural ventilation. Natural ventilation is far removed from ideal ventilation. It is, therefore, eliminated as much as possible, especially by filling or covering the accidental cracks and grooves, and is replaced by ventilating devices.

3. Artificial Ventilation

Ventilating devices must show the following requirements:

1. They must supply fresh air.

2. The choice of apertures for the addition and removal of air must assure a ventilation as complete as can be had without annoying the inmates of the stable with drafts.

3. The ventilation must at all times be able to meet the demands and be easily adjusted to suit the requirements.

When installing a ventilating system one must not be satisfied, as so often happens, with the removal of the used air, but above all one must

bear in mind that the air that is passing out of the space that is being ventilated must be replaced by absolutely good, pure air, and that this fresh air reaches the place where it is most needed by the animals, namely, their heads. The fresh air should be taken from the free atmosphere at a place where a pollution is excluded. It should be led into the stable through special channels, and not simply allowed to enter through opened windows and doors. In the latter case when the outside temperature is colder the upper part of the door opening represents the exit, the lower part the inlet of air.

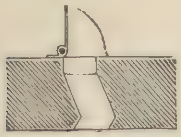

Fig. 172. Horizontal ventilation with trap. *a*, Outer, *b*, inner surface of wall.

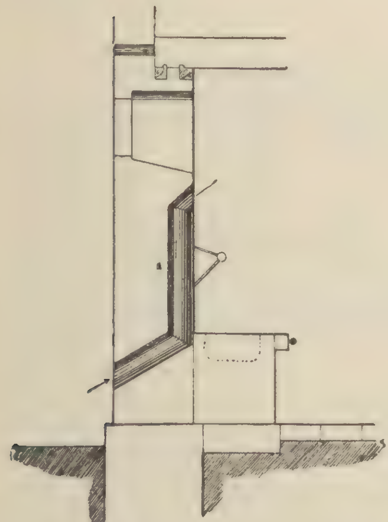

Fig. 173. Improved horizontal ventilation.

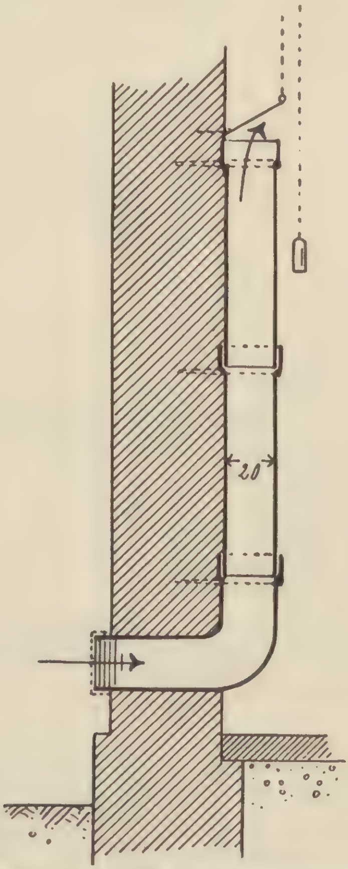

Fig. 174. Horizontal ventilation subsequently built in with tile.

To accomplish as complete ventilation as possible the apertures for letting air in and out should be separated as far as possible. Drafts are avoided by allowing the air to enter the stable through many small openings.

Efficiency and ability with which the devices for ventilation can be regulated depend on the motive power. The motive forces to be con-

sidered are (1) the wind, (2) variations in temperature, (3) machines. Our choice should, almost without exception, be limited to the first two. Machines should be considered only in rare instances. The former have the disadvantage, however, that they are not dependable. On hot, still summer days, when a vigorous ventilation is especially needed for animals that are being kept in the stable, they fail entirely.

For dwellings this trouble has been overcome with especially constructed machines, which for pecuniary reasons will hardly become widely used in stables. By means of water turbines, gas or electric motors or steam engines, turbine-wheel ventilation is conducted by suction of the utilized air and forcing in good air. The cost of maintaining ventilation by means of machines amounts to 1 to 2 pfennings (¼ to ½ cent) for every 50 cubic meters of air.

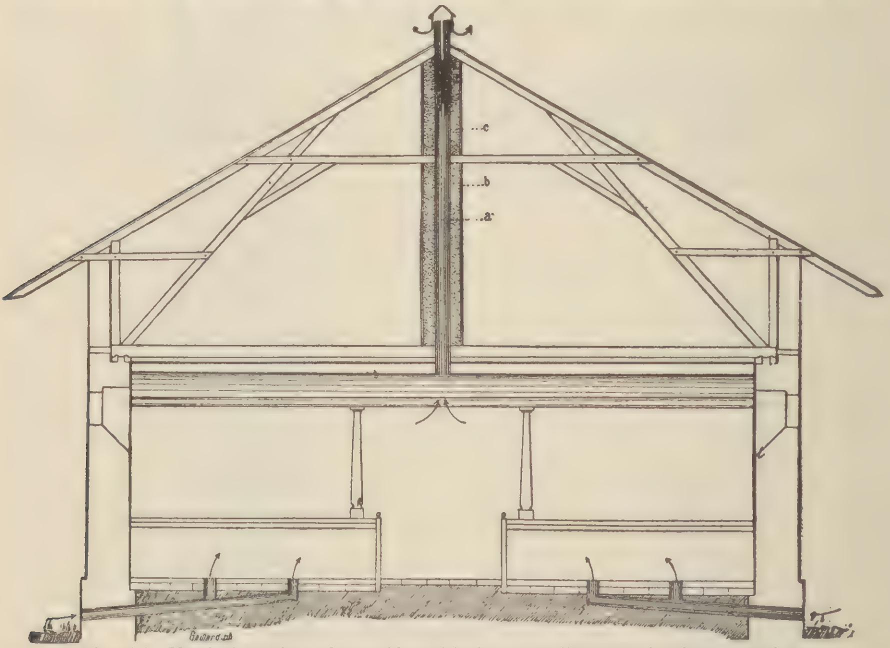

Fig. 175. Vertical section of a stable, with floor ventilation and ceiling aeration.

A distinction is made between horizontal and vertical ventilation, according to the direction of the stream of ventilation, whether it passes into or out of the stable in a predominantly horizontal or vertical direction. Ventilation through open doors and windows has already been referred to.

Horizontal ventilation is frequently found in farm cattle barns in the form of round or square shafts about 10 to 15 centimeters (4 to 6 inches) in diameter, installed near the ceiling at intervals of about two or three meters (yards) and that penetrate the walls directly or brokenly (see Fig. 172). Sometimes the shafts are deflected in a slanting direction, downward and outward, and then allowed to open within on the window sill. It is still better to allow the channel to turn off at a right angle

and to follow the wall for a considerable distance (1 to 1.5 meters), if possible near the inner surface of the wall (see Fig. 173). In old stables such a system of ventilation can easily be installed later by means of tile (see Fig. 174). Such an arrangement offers the advantage that the force of the wind is broken and the air that enters is slightly warmed in the long conduit. Furthermore, the air that enters is deflected obliquely upward, which causes it first to mix with the stable air before it settles down upon the animals.

Sometimes the incoming air is also led through a shaft which begins at the outside slightly above the level of the floor, penetrates the wall, passes under the feed passage, and ends several centimeters (a few inches) above the floor at a level with the crib, where it is turned away from the animal. The opening is provided with a screen (Fig. 175). This system of ventilation is used when the animals are not stabled with their heads toward the wall but with their heads toward the center line

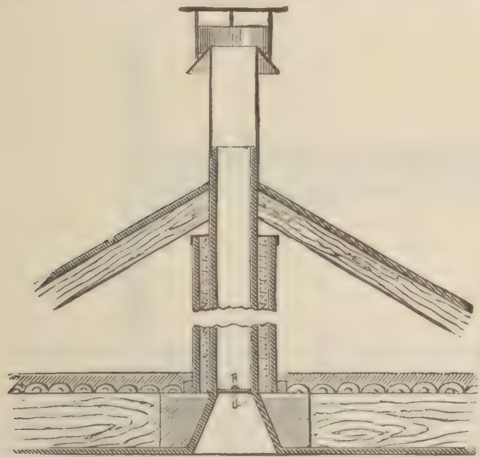

Fig. 176. Vapor or fume flue.

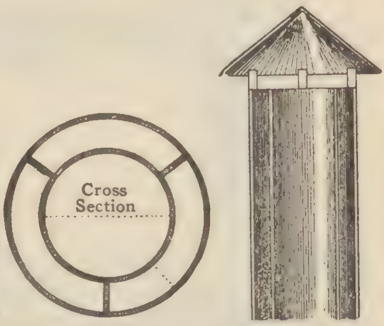

Fig. 177. Ventilation arrangement of Kinnel.

of the stable or toward various feed passages that meet the center line at right angles (Fig. 175). One aperture is allowed for two or three cattle. Floor ventilation often has the disadvantage during the cold time of year of causing the air that enters to mix poorly with the warm stable air, and rather to spread out over the floor. The animals then lie in the cold and are subject to catching cold.

The motive force of this horizontal system of ventilation is chiefly the wind, which forces the fresh air into the stable from the wind side and sucks out the impure air on the other side which is protected from the wind. A great objection to the horizontal system is that its efficacy is chiefly dependent upon the wind and that during a calm it almost entirely fails to work. It is necessary to provide the outer openings of the air channels with wire netting or with tin perforated with large holes,

and the inner opening with a trapdoor, in order to be able to regulate this ventilation to a certain extent.

Vertical ventilation is somewhat more reliable than horizontal ventilation. The motive force here, if no special measures are used, is the difference in temperature between the air within and the air without. The vertical system of ventilation consists, in its simplest form, of a shaft of about 20 to 50 centimeters (8 to 20 inches) in diameter, which begins with an opening in the middle of the ceiling of the stable and extends in a fairly straight line to above the roof, ending there with its opening covered so as to keep out rain and snow but also arranged so as to allow the air to pass out freely (see Fig. 176). To bring the ventilating shaft lower into the stable is useless, as the efficiency of the system would thus be decreased. Such "vapor flues" or "vapor consumers" are often constructed in the country out of four boards, smooth on the inside and fitted together into a square. To make the boards more impervious they are covered with tar paper and then faced with

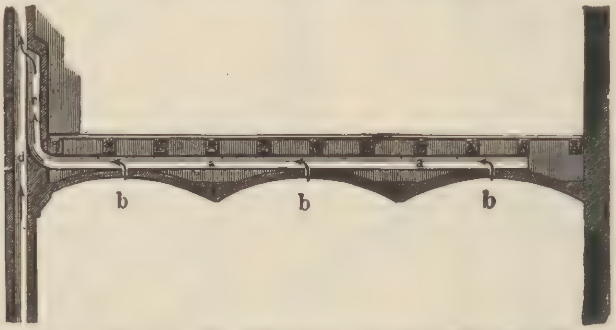

Fig. 178. Longitudinal section of a stable with arrangement for withdrawing the air toward the flue.

another layer of boards, or the flues are constructed of masonry or of sheet zinc or tile pipe. To prevent the air in the flue from cooling off, which greatly influences the efficiency of the device and also would cause the condensation of water vapor, the flue is encased in poor conductors of heat, such as straw, chopped straw, sawdust or other insulating materials. If in spite of this insulation a disturbing amount of condensation of water vapor and a dripping of water from the flues takes place, a "sweat drain" should be put up for the "sweat water." The vertical ventilation system should also be provided with traps so that the current of air can be checked if necessary. A flue of about 20 centimeters (8 inches) in interior diameter is allowed for 6 to 8 large domestice animals.

Such simple flues serve only to carry away air; therefore, in addition to them a means of bringing in air must be provided. The admission of air is often accomplished by horizontal ventilation, or, according to the suggestion of Kinnel, a flue constructed of sheet metal may be surrounded by a larger pipe (Fig. 177). The stale air is supposed to find

its way out through the inner tube and the cooler, fresh air is supposed to sink down into the stable between the outer and inner pipes, during which process it becomes slightly warmed by the warm air that is passing out through the inner pipe. But since this cools off the warm, damp air that is passing out, a decided condensation of water vapor results, which often causes trouble. This, furthermore, lessens the difference in temperature between the air that is coming in and that which is passing out, and consequently lowers the efficiency of the system of ventilation.

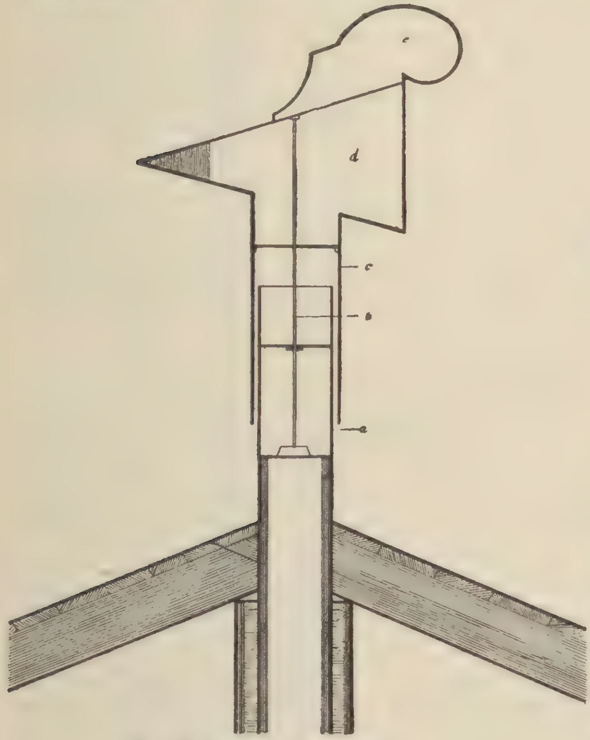

Fig. 179. Aspiration head piece.

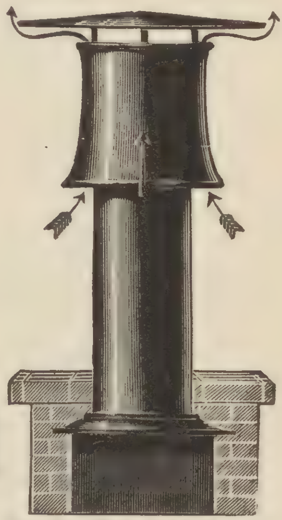

Fig. 180. Wolpert's aspirator.

Since the difference in temperature between the stable air and the outside air is considerable except during the hot time of year, the vertical system will generally work satisfactorily, although it will fail to work when the outside temperature is high. An attempt is made to overcome this defect by utilizing the movement of the air as motive force with the vertical ventilation, but less often by artificially warming the air that is passing out. For this purpose a decoy flame is adjusted at the lower end of the flue. The stable lighting system can also be utilized for this purpose. Or sometimes the vertical ventilation is connected with the chimney of a furnace. The ventilating pipes that are located in the top of arches of the ceiling are led into a well-insulated collecting chan-

nel of about 15 centimeters (6 inches) in width, which extends toward the chimney, passes along its warm wall for 1 or 2 meters, and then enters into it at an angle (see Fig. 178).

To utilize the wind as a motive force for vertical ventilation, several devices have been recommended, of which the following will be mentioned here:

1. The exhauster head or aspiration head piece, which is constructed in various forms (Fig. 180). Occasionally it is constructed as shown in Fig. 179. According to this it consists of a tin pipe that is bent at a right angle; the horizontal arm ends short in a trumpet-like opening; the vertical arm is fastened upright and so that it revolves upon the flue. In order that the opening of the horizontal arm will automatically turn away from the direction of the wind, it is provided with a weather vane. Sometimes the exhauster head is constructed after the manner of pulverizing apparatuses.

2. According to Muir, the flue should be divided into four parallel channels by partitions placed crosswise (see Fig. 181 and 182). The partition walls should project above the channel at the upper opening, so that the wind will blow in on one side and be sucked down on the other. As a total cross-cut 500 square centimeters is usually advisable. One Muir ventilating flue is allowed for about 12 cattle.

As has already been mentioned, the stale air is often carried out through the flue pipes and the fresh air is allowed to enter through the horizontal ventilation. For such a *combined ventilation* Schreider recommends that the pure outside air be led in through wooden channels, which are placed directly under the ceiling diagonally across the stable, and be allowed to emerge from these shafts through openings 10 to 16 millimeters (3/8 to 5/8 inch) in diameter which are made in the side and bottom walls of the shaft. With this arrangement the cold air sinks slowly and in thin streams and mixes so thoroughly with the warmer air of the stable that drafts are avoided. Schreider also recommends wooden air shafts for carrying off the stale air. According to Schubert, every ten cattle (of an average of 500 kilograms) should be allowed four shafts that bring in fresh air, each shaft 14 by 21 centimeters (5½ by 8 inches), or two shafts each 14 by 40 centimeters (5½ by 40 inches) cross section, and one outlet flue of 30 by 30 to 33 by 33 centimeters (12 or 13 inches) cross section, or, in case of round shafts, 35 to 40 centimeters (14 to 16 inches) in diameter. The ventilation should be regulated by traps.

The efficacy of artificial ventilation can easily be estimated by the velocity of the air coming in through the sum total of the openings for ventilation. To determine the velocity of the air differential monometers or anemometers have to be used (page 33). With the vertical ventilation the velocity of the air (v) can be determined by the difference in temperature (t-t′) of the inner and outer air, the height of the flue (h) and the fall velocity ($g = 9.81$) according to the equation $v =$

$$\frac{2hg \times (t-t')}{273+t}$$

The amount of admitted air equals the product of the transverse section and the velocity of the air passing out.

For a control test of the entire ventilation system, use is made of the easily conducted carbonic-acid test of the air of the stable that is being ventilated. It is also advisable with cattle and hog barns to take into consideration the relative humidity (page 27), which can be read off instantly, and in horse stables the amount of ammonia (page 32).

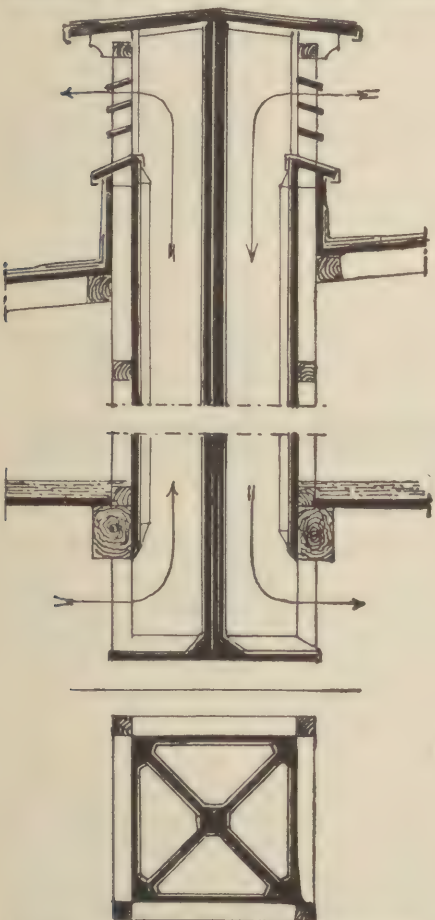

Fig. 181. Vapor or fume flue with four parts.

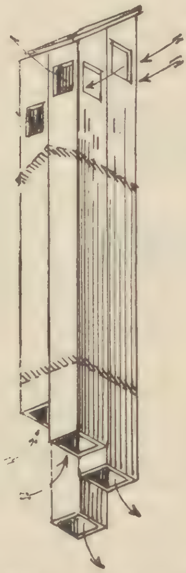

Fig. 182. Vapor of fume flue according to Muir.

VII. Floor and Gutter

The *floor of the stable* should be about 25 centimeters (10 inches) above the ground level, and the entrance should be approached by a slightly rising platform. In addition the doorsill should project 4 to 8 centimeters ($1\frac{1}{2}$ to 3 inches) to the outside. This prevents water from running into the stable even during the severest downpour of rain.

A stable floor which will meet all requirements must possess certain qualities, among which the following should be mentioned here:

1. The stable floor must be impervious. A pervious floor would absorb urinary and fecal constituents which would then decay and result in the formation of carbonic acid, ammonia, and various foul-smelling, harmful gases, which pollute the air of the stable. The animal's excrement, which is rich in organic substances, also acts as a favorable nutrient medium for various dangerous disease organisms. The disease germs that have penetrated into the pervious floor can remain viable and virulent for months and sometimes even multiply (tuberculosis, fowl cholera, bovine hermorrhagic septicemia, swine plague, infectious abortion, foot-and-mouth disease, strangles, several organisms causing inflammation of the udder, etc.) To the latter belongs the anthrax bacillus, which, under the conditions existing in a stable, not only thrives but even develops spores which must be especially considered with re-

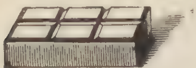

Fig. 183. Grooved bricks.

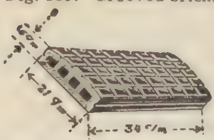

Fig. 184. Hollow bricks for stable floor.

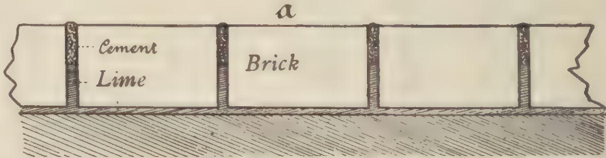

Fig. 185. Laying the bricks.

gard to the spreading of anthrax; furthermore the swine erysipelas bacillus, the *Bacillus necrophorus* (which causes infectious, necrotic foot rot in sheep, necrotic inflammation of the vagina of cattle, particularly after difficult birth, multiple necrosis of the liver, and calf diphtheria). *Bacterium coli* as a cause of inflammations of the udder, calf scour, etc., the causative agents of malignant catarrhal fever of cattle, bacillary swine typhus, various wound diseases, malignant edema, etc.

The causative agents of disease that exist in and on the floor of the stable can in many ways again find their way back into the body of the animal and cause disease. It is thus very possible, for example, that during urinating the urine might splatter the disease germs from the floor into the litter or feed, and that the germs would then be taken up with the latter; or that the tail might become polluted with infectious substances and then brush the disease germs on the genitalia, whence they could penetrate farther into the passages; or that the genitalia might come in direct contact with the infected floor of the stable and with the liquid manure and thus become infected (*e. g.,* infectious abortion).

Since, as has been shown, the causative agents of disease can easily be transmitted from the stable floor to the animal, special attention must be given to the floor when the stable is being disinfected. Absorbent floors should be replaced by impervious ones.

2. The floor of the stable should be level. An uneven floor is uncomfortable for animals lying down; they can not rest properly, which is of great importance, especially with animals that are used for work. A very uneven floor (paved with cobblestones) may even torture the animals. Uneven floors also produce bruises. In cattle and other animals this may often result in an enlargement or conglobation, a tumor-like swelling, edema of the knee (carpus) which can grow larger than a man's head. With horses an uneven floor often prevents them from having a sure footing. Stretching and tearing of the ligaments of the horses that lose their footing may result and develop into inflammation and lameness.

3. The floor of the stable should have a rough surface. Animals slip easily on floors that are too smooth and as a result often suffer from stretched and torn ligaments; or they may even fall—causing bruises of various kinds, broken bones, abortion with animals that are pregnant, etc.

4. The floor of the stable should be soft and elastic, to make standing and lying comfortable for the animals.

5. It should be warm, so as not to cause diseases due to chilling.

6. The floor of a stable should be durable, so as not to wear out soon.

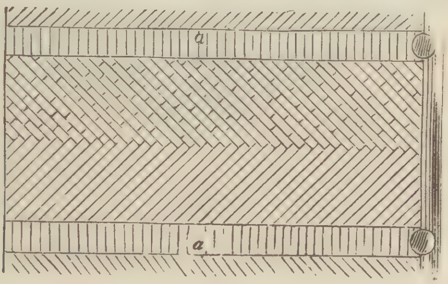

Fig. 186. Brick pavements.

No kind of floor can meet all of these requirements satisfactorily, and the softness can be combined least with durability. The clinker and brick paved floors have given the best results for horse, cattle and hog stables, and also cement and asphalt floors for cattle and pigs. The poorest floors are those paved with cobblestones or made of plank or earth.

The clinker-paved floors are made of well baked, grooved bricks (see Fig. 183), so-called clinkers (vitrified brick). These are placed flat upon a firmly packed soil or cement foundation (Figs. 185 and 187), or in horse stables are often set upright on edge, in which case the rows are arranged so as to run obliquely toward the center of the stall (dovetail —Fig. 186). Occasionally ordinary bricks are used in place of clinkers. They are not so satisfactory for shod horses, as they are not very dur-

able. In addition they are rather porous, but are warmer and softer than clinkers. The latter is especially true of the Swiss patent hollow bricks used for stable floors. These are especially well adapted for cattle and hog stables (Fig. 184).

Hard-baked clay slabs, 25 centimeters (10 inches) square and 6.5 centimeters (2½ inches) thick, with hollow spaces running lengthwise, are recommended for hog pens. The top surface should be made slightly rough. The hollow spaces protect the floor to a great extent against cold. These bricks are set in cement mortar on a thin layer of concrete.

Every clinker is set half its depth into lime and the upper half of the grooves are carefully filled in with cement (Fig. 185). To make it possible or easier to fill this groove with cement it is advisable to have the grooves 6 or 7 millimeters (¼ inch) wide.

To increase their durability and imperviousness the clinkers should be saturated occasionally with coal tar. Such a paving is impervious, level, rough, and durable even for horses that are shod. It is relatively warm and not too hard. It is suitable for horse, cattle and hog stables.

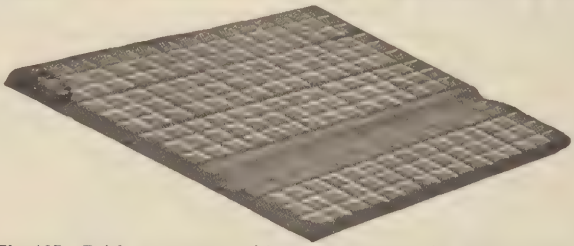

Fig. 187. Brick pavements with manure gutter for horse stable.

The Mettleacher paving bricks, Munich trottoir (sidewalk) stones, etc., have the same properties as the clinker paving, with the exception that they have a somewhat greater hardness. But they are more expensive than the clinkers and consequently are used almost solely in stables for fancy horses. A layer of concrete or leveled-off building stones is used as foundation. To prevent the horses from slipping on these artificial stones that are usually smooth, the stones are made with cross-hatched indentations.

Special mention should be made of the Doerrit artificial flagstones made in Munich. They are made by compressing coarsely ground hard stones with asphalt that is resistant against acids and alkalies. These flagstones are hard, durable, impervious, rough, and fairly warm. The porphyry flagstones manufactured at Ostrau are made of crushed porphyry and cement under high pressure and are rough and durable. These and the Doerrit flagstones are laid upon a thin foundation of concrete and are tightly packed with cement.

Concrete floors are made of cement, sand, gravel and crushed stone laid on a layer of cinders or coke slag, 30 centimeters (1 foot) in depth. They are impervious, easily cleaned and disinfected, level and durable,

but have the disadvantage of being smooth, hard and rather cold. The smoothness can be partly overcome by marking with grooves (scoring) and above all by mixing cinders or sand with the upper, unsmoothed mass of concrete. These floors are not satisfactory for horse stables because of their smoothness, but are better for cattle and especially for cattle and hogs that are being fattened. They are generally too cold for young pigs, especially if in addition to the cement floor the pens are separated by cement partitions. Under such conditions it is often noticeable that young pigs more often contract chill diseases (catarrh of the respiratory organs, cough) and that thus the foundation is particularly laid for swine plague, a widespread disease especially among young stock. To avoid colds the walls in breeding stables are often constructed 30 centimeters (1 foot) in thickness, and the floor, that must have sufficient fall, is covered with poor conductors of heat, e. g., wooden boards or laths, or at least the stall should have wooden battens as extra flooring, which can be removed during disinfection, and as they can not be disinfected

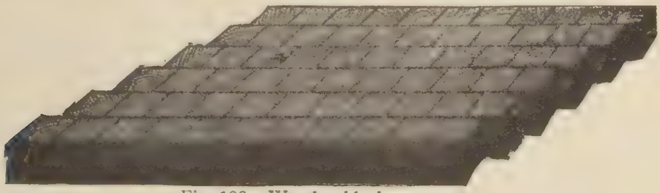

Fig. 188. Wooden block pavement.

satisfactorily they must be burned and replaced by new ones. A similar procedure is carried out in the stables of milk cows; planks are laid on the concrete floor; sometimes even a layer of sawdust is put between. To keep this floor dry and warm it is given a depth of only 16 to 18 centimeters. If of greater depth, then the boards should be protected against decay with wood tar or carbolineum (creosote oil) and the sawdust should be ommitted. It would be hygienically better to make the concrete surface rough and to cover it with Doerrit paving. The Doerrit paving has proved itself durable, impervious, warm and elastic because of its content of asphalt.

The asphalt floor is usually made of a mixture of sand or coal cinders (to remove the smoothness) and asphalt, placed upon a floor of concrete or bricks, sometimes on firmly packed earth, to a depth of 5 centimeters (2 inches). It is impervious, level, and relatively soft, warm and durable. It is unfortunately slippery when in a wet condition, which can, however, be remedied by scattering a thin layer of sand over it. This floor is especially well suited to cattle and hogs. It is not so satisfactory for horse stables, as it is not durable enough for horses that are shod, as, for example, the clinker paving is. Nevertheless it is included in the list of floors that are best for horse stables and is used often and satisfactorily for that purpose.

Stone paving is impervious, level, and durable if constructed of well-hewn stones (granite, syenite) firmly cemented together; but on the other hand it possesses the disagreeable quality of being hard and cold. By mixing sand with the cement and by means of scoring the smoothness can be overcome with this paving. The same conditions exist with paving of sandstone, granite and hard limestone, which, in addition, are also somewhat more expensive than the ordinary stone paving.

Wood-block paving (Fig. 188) is made of oak blocks. To make the wood impervious to liquid manure it is saturated with hot coal tar. To make it more durable it is laid with the flat side upward, on a level foundation covered with tar, and then the cracks are filled in with cement or tar. Sometimes only the front third is paved with wood and the rest with clinkers. The greatest disadvantages of the block paving are the high cost, the insufficient imperviousness and the relatively low durability for horse stables. The slightly disagreeable smoothness that arises

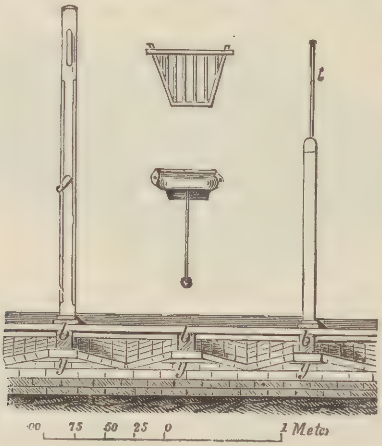

Fig. 189. Stall bridge.

when the paving is wet or new can easily be overcome by strewing some sand on the floor. The block paving is used almost exclusively in stables for fancy horses and in stallion depots.

A floor made of planks is pervious. If the planks are new and wet from urine they are also very slippery. They are not very durable; they soon deteriorate from decay and from the action of the horses' shoes, and when the animals stamp their feet the liquid manure wells up between the planks and leads to a softening of the horny part of the hoof (frog rot) and to dermatitis of the hind feet (scratches). Attempts have been made to overcome these disadvantages by draining off the urine that seeps down through the planks by giving sufficient slope to the impervious foundation beneath, e. g., to construct so-called "stall bridges" (Fig. 189). The advantage of this arrangement is, however, very slight, for even with a suitable fall and with frequent rinsing with water a

great number of substances that can easily decay and lead to pollution of the air remain upon the foundation under the planks. In addition, causative agents of disease will in some instances settle there. It is a known fact that pectoral influenza among horses, swine erysipelas, etc., occur more frequently and in a more malignant form in stable with such wooden floors, with or without the hollow space beneath, than in stables that have floors that are hygienically unobjectionable.

Wooden floors are used in the summer stables of cattle in the Alps and in many mountainous districts, but are found less often in Holland, Friesland and the southern part of Sweden (Skone). The stalls are usually short so that the feces and urine fall into the manure gutter as with the Dutch stalls. The floor is usually made of boards, less often of planks. Litter is seldom used. Such a floor is smooth when new.

For cattle the wooden floor possesses an advantage over all solid floors in that it is warm, dry (Dutch stabling), soft and elastic, and for this reason allows considerable saving in litter. It is advisable to saturate or paint the wooden floor with carbolineum (creosote oil). If the painting is repeated when necessary, and if alder, larch or oak wood is used, the floor will be resistant against decay for a long time.

The construction is carried out as follows: The soil is leveled off, covered with gravel or broken stone packed down, and then made absolutely impervious with hot, thick coal tar, which is applied with a stubby broom. After this has dried three saturated timbers and placed parallel with the stable alley, the first one just in front of the crib, the last one in front of the stall gutter, and the third in the middle. The spaces between are filled in with clean, dry sand and then the planks are nailed on. In short stalls for cows the planks are laid horizontally; in ox stalls they are given a fall of 2 centimeters (¾ inch).

The wooden floor has the disadvantage that it can not be disinfected satisfactorily. If a thorough disinfection of the floor is necessary it must simply be replaced by a new floor.

Cobblestone paving is constructed by tamping the stones, even very rough stones, into sand. It is above all porous, uneven, and hard, therefore not at all to be recommended from a hygienic point of view. This type of floor is found most frequently in the country in horse and cattle stables.

The dirt floor consists of packed loam or clay, less often earth, sometimes mixed with stand. This kind of floor is common in hay barns (threshing floor) and is frequently still used for sheep stables. This floor is pervious and not durable for larger domestic animals and for hogs. It is sufficiently durable for sheep stables, in which it is usually covered with a layer of sand 15 centimeters (6 inches) in depth and with the litter. A boggy condition is to be feared less here, since sheep discharge dry feces and only a relatively small amount of urine, and scatter it about over more surface, as they are in the habit of moving

about freely in the stable. The dirt floor is used most frequently for exercising stables for foals and for stabling brood mares in which the foals and mares are free (not tied) and must be protected from slipping. In addition to the disadvantages resulting from the perviousness there is the added disadvantage that the urine can not drain off properly. The urine collects in the places that are trodden down and decomposition sets in. The urine so rich in ammonia attacks the horny part of the hoof and loosens it. Hoof diseases, especially thrush, with its resulting conditions are often provoked in this way. The dirt floors are suitable only for cattle in the stables on marsh land and having Dutch stable arrangement (Fig. 192).

Mortar floors made of firmly packed, slaked lime, which is usually mixed with peat ashes, are to be considered about the same as dirt floors.

Closely related to these two latter types of floors is the floor made of air-dried bricks which used to be recommended for cattle stables. With the Dutch stable arrangement (page 267) there is little objection to be raised against this soft and warm floor, which at the same time replaces the litter to a certain degree, in spite of its perviousness and porosity; but for stalls of the usual length it is objectionable. A boggy condition soon results.

In recent times the Association of German Hog Breeders has advised that the part of the stall that serves as the bed should be left unpaved. The unpaved part is pervious and must be removed as soon as it is badly soiled, and then must be replaced with new soil. The dry earth is soft and warm. The bedding may be omitted. Chill diseases, especially among young pigs, are avoided.

When the young pigs push against the udders of the mother sow their lively kicking movements have the effect of pushing the bedding behind them. After they have satisfied their hunger they always lie in direct proximity to the mother during the first days of their existence. If the young pigs thus lie for hours on the stone paving (cement floor, etc.), which has been bared of litter, they lose much of the warmth which is provided by the bedding. Colds, intestinal catarrh and lung diseases often result and are then the chief causes of more serious diseases among the young pigs. If, on the other hand, the floor is of earth, it is generally not dangerous for the young to lie upon it. Earth floors, in contrast with stone floors, concrete floors, etc., prevent colds and have the advantage of being inexpensive. The resting place is kept clean by the hogs themselves. They deposit their urine and feces outside in the front, paved part of the sty. The part that is not paved is surrounded by a firm, wooden frame, to prevent the hogs from rooting under the paving and tearing it up. Sand, cinders, chopped twigs, short stray, etc., are often used in place of the soil. Pervious floors naturally make disinfection difficult.

In judging the floor of a stable *the fall* must be taken into consideration. The floor should slope so that the urine can flow off well but that on the other hand the animals are not annoyed or made sick by the fall.

In horse and cattle stalls the fall should be from the crib toward the urine gutter. The first third to the second third part is often kept level. The sloping surface should have a gradual fall and should not have any troughs. Even though a greater fall drains the urine off better and more quickly than one not so great, the fall must be kept within narrow limits out of consideration for the animals. With too great a fall the result will naturally be that the body weight of a standing animal bears too heavily upon the hind legs. Horses, which often do not lie down at night, can not rest sufficiently under such conditions, and their hind legs become overtaxed, which favors the development of tendonitis and arthritis. To relieve the gluteal muscles as much as possible, horses that stand upon a surface that is not level place their hind legs farther back; as a result the toe part of the hoof is more burdened and worn off more, which finally leads to stumpy hoof, contracted heels, upright fetlock position, or knuckling. Stalls with a decided slope are especially disadvantageous for pregnant animals, in which case the intestines are displaced toward the rear, thus causing them to press harder upon the uterus than they should, and it is said even resulting in abortion. Furthermore the genital organs are pushed backward, which may cause a prolapse of the vagina and uterus.

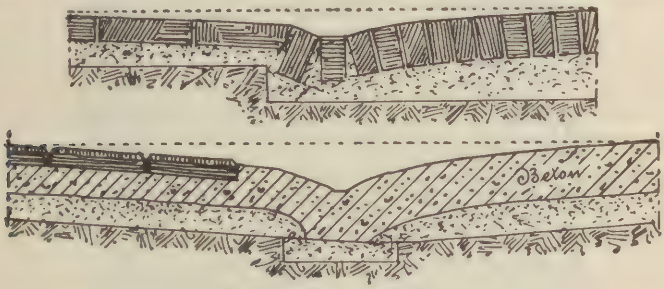

Fig. 190. Manure gutters.

The *gutter arrangement* of the stable must carry the urine and cleaning water outside as quickly and nearly completely as possible. If these liquids are allowed to stand in the stalls they will soon decompose and pollute the stable air; furthermore, they act as nutrient medium for certain disease organisms and aid in spreading the particular diseases. Finally, they would also cause the animals to become filthy and cause the horny part of the hoof to become saturated as well as loosened by the decomposed urine because of the high content of ammonia.

The gutter should be constructed of impervious material (concrete, hard clinkers set in cement, asphalt). It passes along the back of the

stalls at right angles to them and is left open so as to be easily inspected and swept out (Fig. 168). In horse stables these gutters are shaped like flat troughs (see Figs. 187-190), to prevent the horses from getting

Fig. 191. Stable arrangement (Holland).

their feet wedged if they step in and from tearing ligaments and tendons. In cattle and hog stables such precautions need not be taken; the greatest stress should be placed upon good drainage, which is effected by

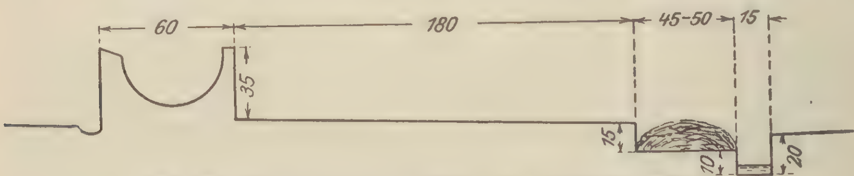

Fig. 192. Stable arrangement (Holland) in instructing stable.

increasing the fall and having less width. In horse stable the gutter for urine is given a fall of 1 centimeter in 1.5 meter (1 inch in 12 feet); in cattle and hog stables from 1 centimeter in 1 meter (1 inch in 8 feet).

With the Dutch stable arrangement for cattle the urinal gutter is usually constructed with a depth of 40 centimeters (16 inches) and a width of 50 centimeters (20 inches) (Fig. 192). Sometimes the fall into the gutter is divided into two sections; the part nearest the stall is built 25 to 50 centimeters (10 to 20 inches) wide and 15 to 20 centimeters (6 to 8 inches) deep; the part next to the stable alley 15 to 25 centimeters (6 to 10 inches) wide but 25 to 50 centimeters (10 to 20 inches) deep. The dung is usually deposited on the first part; the second, deeper part serves as the real urinal gutter.

In order not to have to make the urinal gutter in long stables too deep toward the exit, the liquid is carried off through subterranean channels, or the deeper parts of the gutter are covered with perforated iron sheets (iron grating). The covered gutters and underground channels should be avoided as much as possible, as it is very difficult to clean them. The underground channels are usually made of glazed clay pipe (sewer pipe), not too narrow. To avoid clogging as much as possible the greatest possible fall should be given. The underground pipes connect with the urinal gutter on one hand and with the urinal container or manure pit on the other, and are therefore not simply open. Otherwise during the colder periods of the year the warm, damp and consequently lighter stable air which escapes upward through the ventilating apertures, cracks, grooves and pores could, through reacting, draw into the stable the air in the pipes which has become greatly polluted by gaseous products of decomposition. The air will be especially bad if, instead of the pure air of the open atmosphere, the sewer gas[6] that stagnates around the opening of the pipes that lead into the manure pit is drawn in. Under such conditions acute sewer, gas poisoning, oftener chronic poisoning, may result. The symptoms of the latter are dullness, weakness, anemia and diarrhea. These disadvantages can be easily overcome by adjusting a so-called water or gas trap.

The water or gas traps are constructed in several different ways. The S-shaped trap used so often in kitchen drains is also frequently used in stables in a flat form. The presence of fluid checks the gases from penetrating (see Fig. 193). This is further accomplished by placing the drain sewer near the bottom of the urinal container, thus letting the urine close it (see Fig. 194). Those provided with a lid are very satisfactory, if the tops are easily accessible (Figs. 195 and 197). They consist of a pot-shaped box which is sometimes provided with a grating that can be lifted out (Fig. 197). The liquid remains at the same level as the mouth of the drain pipe. Figs. 196 and 200 show two other types.

The *manure pit* should be located several yards from the stable, so that the odor can not penetrate too easily through open windows, etc.,

[6]Quantities of poisonous gases are produced by the decomposition of urine and feces. Eresmann, who has made a study of the gaseous products of the decomposition of human excrement, found that the excrement of a medium-sized cesspool gives off 5.5 cubic meters of carbonic acid gas, 2.5 cubic meters of ammonia gas and 20 liters of hydrogen sulphid gas with a consumption of 13.85 cubic meters of oxygen.

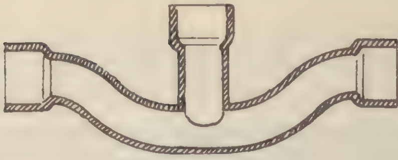

Fig. 193. Gas trap.

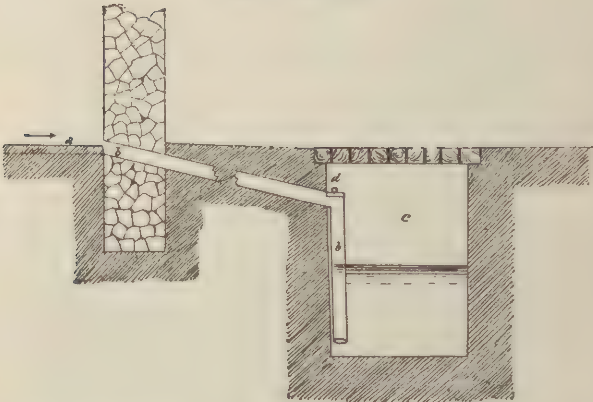

Fig. 194. Drain for urine and liquid manure with water trap.

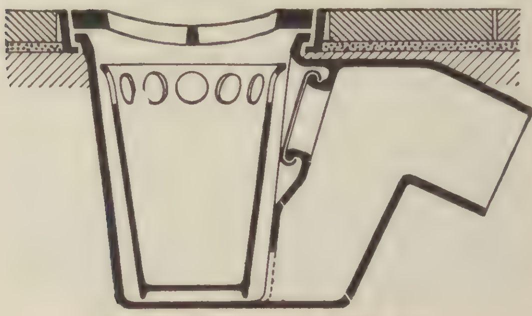

Fig. 195. Cross section of basin trap.

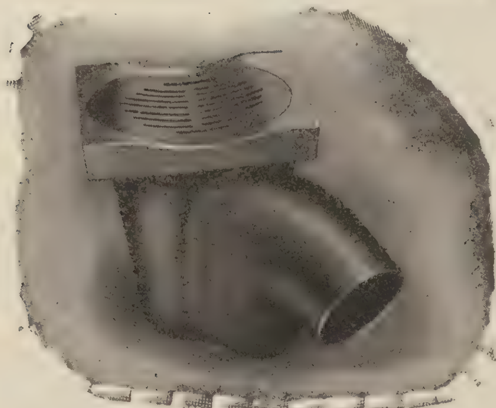

Fig. 196. Basin trap from without.

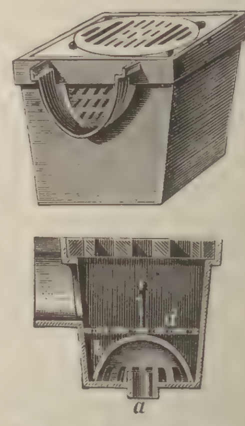

Fig. 197. Drainage basin.

Fig. 198. Transportation of feed by means of elevated cars.

Fig. 199. Elevated cars on cables for transporting feed.

into the stable. The walls and the floor should be constructed of impervious material, and the outer surface of the wall should be surrounded with a layer of clay or a thick layer of loam. In this way we can prevent ingredients of the urine and feces from penetrating into the surrounding soil and thus on the one hand becoming lost and on the other polluting and infecting the soil, which should be particularly avoided if a well is located within a radius of 10 meters (11 yards). The dimensions for a manure pit are estimated at 3 to 4 square meters (10 to 13 square feet) per cow, 2 to 2.5 square meters (7 to 8 square feet) per horse. To prevent the sun from drying out the manure, trees are frequently planted near by, or a roof is built over the dung pit (northwestern Germany). To prevent the rain from washing out the manure the flow of surface water should be kept away.

The *urine pit,* for the reception of the urine that flows from the stable as well as from the dung pit, is just as necessary and should like-

Fig. 200. Grating over channel.

wise be impervious. Three cubic meters (yards) are allowed for 10 head of large stock. The urinal pit should lie beyond the ground of the stable.

In stables with modern equipment a tramway is often built for the transportation of the manure and feed. The cars on rails have the disadvantage of disturbing the traffic on the level ground and making the cleaning of the floor more difficult. For this reason the elevated cars or carriers (with cables and tracks) have frequently been adopted (Figs. 198 and 199).

VIII. The Bedding

1. The litter should provide the animals with a dry, clean, soft, and warm bed during the cold time of the year.

2. The bedding should be free from things that are injurious to health (large quantities of mold, fodder fungi, poisonous plants, etc.; see appropriate chapters). This is especially true of the litter that is used in the front half of the stall. Parts of diseased plants are also not suitable for bedding, because they may become an important source of infection for susceptible, cultivated plants by being carried to the fields

with the manure. Tambark which contains white lead may cause lead poisoning.

3. The litter should enrich the manure with valuable constituents, in that it absorbs the solid and liquid animal excretions, retains them and combines them, and aids the normal process of decomposition in the dung.

A generous supply of litter is necessary for lying down, since an impervious floor without litter is generally too hard and too cold. Lying on a bare floor during the cold weather can easily cause wetting and colds (diarrhea, catarrh), especially with younger animals. Litter is also desirable for animals that are standing, as it protects the hoofs as well as all the limbs. Standing on a hard floor is tiring and does not give the horses the same rest as they get upon a softer foundation. When horses stamp with their feet to drive away flies the joints receive greater shocks upon hard floors than upon soft floors. Purebred horses with legs that are covered with fine hair do not like to urinate upon a hard floor because of the spattering, and for this reason lack of litter may cause the horse to hold back the urine, which produces serious results.

The quantity of bedding required varies according to the kind of animal, the material used for litter, etc. Straw is largely used as litter. Stebber notes a yearly use of litter of an average of 700, an average use of 700 kilograms (1,540 pounds) a year, or about 2 kilograms (4.4 pounds) a day, per head of large livestock. According to his reports 1600 to 2200 kilograms (3,520 to 4,840 pounds) of litter is used in sections that raise an abundance of hay, while 500 to 600 kilograms (1,100 to 1,320 pounds) is used where straw is not plentiful. In general the necessary yearly supply of bedding for a horse is estimated at 700 to 1000 kilograms (1,540 to 2,200 pounds); for a cow at 1,000 kilograms (2,200 pounds); for a sheep at 45 kilograms (100 pounds), and for a hog at 300 to 600 kilograms (660 to 1,320 pounds).

Bedding must possess sufficient power to absorb moisture if it is to serve its purpose fully. The ability to absorb water is dependent upon the water content of each particular kind of litter. This can be ascertained according to the principles set down on page 85. The ability to absorb water is dependent especially upon the kind of material used as litter, and with regard to this suitable estimates have been made for the various materials used.[7]

The bedding should, furthermore, be level and light. That which is soaked with liquid manure and filthy with dung should, like the dung, be

[7]In order to determine the water absorption power the following procedure is carried out: A previously weighed quantity of the bedding material which has been cut up into small pieces is placed in a dish and allowed to soak in water for some time. The surplus water is then allowed to drain off by placing the bedding material on a filter paper or in a funnel containing glass wool and then quickly weighing the water-soaked mass in a covered and previously weighed dish. The addition in weight, figured on a basis of 100 weight units of the original weight, represents the water absorption power.

removed often, two or three times a day (at least half an hour before the milking is begun), at which time the stall should be swept clean and the stall as well as the liquid manure gutter washed off. After the stall has been cleaned out each day the old bedding that is still dry is put at the back of the stall and new bedding is put into the front. Cleaning out the stalls but once or twice a week, as is frequently done in cattle and hog stables, is not considered hygienic. Old bedding soiled with urine and dung has practically the same disadvantages in its results as a porous, filthy floor. It furthermore pollutes the air. During the decomposition of animal excretions a large amount of oxygen is consumed, and quantities of carbonic acid and, during the disintegration of the urine, much ammonia,, etc., are formed, as Vollrath's experiments show. He tested the air of two horse stables, in one of which the bedding was not changed, while in the other the bedding was changed periodically. The first gave relatively less space for animals and consequently greater air space for the individual horse. Both stables were kept closed from 6 o'clock until 10:30, i. e., to the time the test was begun. In the air of the stable provided with permanent litter, 5.018 per cent CO_2 and 0.112 per cent NH_3 were found, but only 2.725 per cent CO_2 and 0.094 per cent NH_3 in the one with periodically changed bedding. A greater pollution of the air impairs the health and the power of resistance of the animals; especially a higher content of ammonia can cause catarrh of the conjuntiva and upper respiratory passages.

Permanent litter furthermore offers opportunity to the causative agents of disease, according to their individuality, to continue their existence or even to grow prolifically. The conditions here are also similar to those existing with a pervious floor (see page 284), except that infectious matter in the bedding can more easily gain entrance into the healthy body of the animal than is the case with substances in the pervious floors.

Furthermore the remaining bedding that is saturated with urine also acts directly in an injurious way upon the health of the animals, since it covers them with filth, soaks into the hair, and above all attacks the hoofs, softens and destroys the horn, often causing thrush, loose wall and seedy toe with all the evil resulting conditions, as well as inflammation of the skin of the pastern, the coronary band, etc., which leads to "scratches" in horses, etc.

According to many reports permanent bedding affects the milk yield, and partly for reasons already stated and partly by a decrease in the resistance (e. g., by the appearance of slow catarrh of the respiratory passages resulting from air high in ammonia content) favors the spreading of infectious diseases. Von Arnim Crieven informs us that the number of cases of tuberculosis is decidedly higher with permanent than with periodically changed bedding.

For pecuniary reasons, namely, to save bedding and at times to pro-

duce a rich manure,[8] these rules are often not observed and the old bedding and dung are left in the stable for a long time. For this reason it is usually customary to remove the dung with the layer of sand soaked in urine only two to four times a year from sheep stables, and even in cattle and horse stables this practice has been adopted occasionally.

The permanent bedding is prepared as follows in horse stables: The entire supply of litter for one week (about 13 to 15 kilograms—28½ to 33 pounds) is put on the cleaned, impervious floor of the stall, the lower layers with the straw placed lengthwise, the upper layers with the straw put in loosely and evenly, either cut small or in half, laid criss-cross. The discharged dung is left lying if a fairly rich manure is desired; if, however, only a medium saving of straw is required (military and stud stables, etc.), then the dung should be removed often. The upper layer of the front, dry section of the bedding is scattered on the wet parts and replaced by fresh straw. The bedding that accumulates is not removed from the stable until after one or two months during the summer; during the winter after two or three months and even later, when the lower layer that sticks to the floor is often left lying and the upper one that is dry is again used as bedding.

It is certain that the permanent bedding offers pecuniary advantages by a saving of straw and the production of a valuable manure; but on the other hand there is no doubt that from a hygienic point of view the continued lying of the manure is not, as has been shown, beneficial to the animals, that the health and efficiency of the animals are impaired, and the morbidity and mortality often increase at an alarming rate, disadvantages which far exceed the advantages gained by allowing the bedding to lie. By means of extreme cleanliness, frequent removal of the manure, etc., as is done in military stables, these faults can be lessened substantially.

To protect the bedding as much as possible from becoming polluted by the dung and urine, the Dutch stable arrangement (pages 267 and 292) (see Figs. 191-192) has been introduced. This arrangement, which in general gives satisfaction, naturally has the great advantage of giving

[8]In order that the most valuable constituent of the dung, the nitrogen, may not escape as ammonia—in other words, may not be lost—it has been suggested that the ammonia be fixed, i. e., that it be conserved with gypsum $(CaSO_4) + (NH_4)_2CO_3 = (NH_4)_2SO_4 + (CaCO_3)$, or, better still, with superphosphate of gypsum or kainite (preferably sulphate of potassium hydroxid and sulphate of magnesia besides magnesium chlorid). This conservation of the manure in the stable is also of hygienic interest, for in fixing the ammonia the pollution of the air by decomposition gases is lessened. The fears expressed by Von Schilling and others that the scattering of kainite leads to fatal poisoning are without cause, according to the reports of Gmeiners, Fesers and others. Fesers fed up to 500 grams of kainite daily for some time to pigeons, chickens, sheep and cattle without any injury at all. A more searching investigation must be made before a definite statement can be made as to what extent the kainite may produce cutaneous inflammation of the feet and udder. If such an effect is feared it may easily be avoided by adding an extra layer of straw. The quantity of substances recommended for the conservation of the manure amounts to 200 grams of gypsum daily per cow, 150 grams per horse, 120 grams per head for young stock, and 30 grams per sheep; of superphosphate of gypsum, 500 to 700 grams per cow, 500 grams per horse, 100 grams per sheep, and with kainite about 250 to 500 grams per cow or horse. If strong acid salts or substances which contain free mineral salts, or even free mineral salts themselves, are used in fixing the ammonia in the liquid manure, care should be exercised in proportion to the amount of fixing agent used for a stronger development of carbonic acid, hydrogen sulphid and other harmful gases. If these gases are developed in great quantity in the stable, or if they have access to the stable, they have often caused severe cases of poisoning.

the animals a dry, clean and abundant bedding in spite of the small consumption of straw. The animals and the stable attendants must of course first become accustomed to the broad, deep manure gutter; at first the animals may step into the gutter and suffer sprains, or even while lying down slip down backwards with their hindquarters into the gutter. According to experience in northern Germany, the animals become accustomed to it fairly soon (Schreve).

In hog stables the bed is often constructed on a slightly raised wooden platform of slatted construction (see Fig. 201). The bedding is usually kept clean by the pigs, and only the front part of the stall that lies lower and is often left without bedding is used for the discharge of urine and feces. The front edge of the bed is raised to prevent the bedding from slipping off.

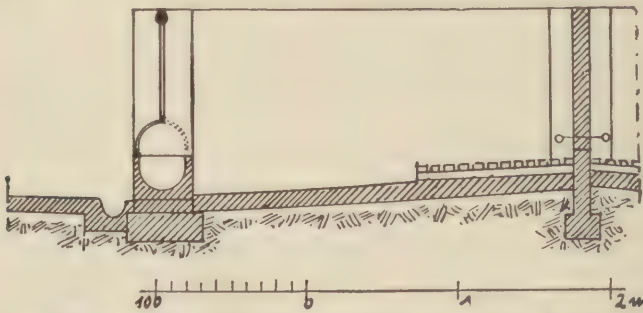

Fig. 201. Pig pen with platform and trough. (The latter has a movable lid.)

a. Bedding Materials

Various materials are used for bedding. The first to be considered are the agricultural products of fields, as straw, chaff, stubble, potato tops, etc.; then of the meadows, such as sedge hay, sour hay, old hay, sea reed, etc.; of the forest (woods litter and leaves); also the refuse of various industries, as sawdust, tanbark, and, finally, peat obtained from the earth.

1. Straw

The most important kinds of straw that even today continue to afford the best material for bedding are those from grains, namely, from rye and wheat, less from barley and seldom from oats. These bedding materials are soft enough and have great power of absorption. According to Heiden, rye straw shows an absorption of 241.4 per cent after 24 hours, wheat straw 225.8 per cent and oat straw 213.6 per cent. The harder, more resistant varieties of straw are best suited for bedding, irrespective of the fact that they are less suitable for use as feed. For this reason the winter grain is to be preferred to the summer grains; the rye and wheat straw to the oat and barley straw. Corn and buckwheat straw are of slight value as bedding.

Good bedding should be dry, not moldy, and free from poisonous weeds.

Grain stubble is used less commonly as bedding, so also the straw or stalks from leguminous plants, and chaff, which is chiefly used for feed. The value of the leguminous straws is less than that of the grain straws when considered as bedding, notwithstanding the fact that some varieties are very absorbent, as, for example the pea and vetch straw (pea straw according to Heiden 281 per cent), but on the other hand its value as manure is much greater than that of grain straws.

The potato tops, rape and poppy straw, which are very brittle and of little resistance, also possess little power of absorption, all of which makes them unsuitable for bedding.

2. Black Bedding

The name "black bedding" can be traced back to the color of these straws. Among them we find—

(*a*) The sedges, which consist of plants grown on swampy meadows (reeds, sedge, rushes, etc.), are useless, or practically so, as feed. In districts that lack straw the sedges act as a very good subtitute. In the Alps province almost as much sedge straw is used as grain straw. It has a greater fertilizing value than straw and is less expensive.

(*b*) The poor hay and old hay are considered only as bedding in Alpine countries. The poor hay consists chiefly of old, tough tasteless sea reed (*Nardus stricta*), which the animals refuse to eat. The old hay is grass that has been left standing on the pasture.

(*c*) Ferns.

3. Bedding from the Woods

The chief bedding from the woods is that which is gathered from the ground and consists of moss, grass, leaves, needles, forest weeds, etc. The power of absorption depends on the combination. According to Ebermayer—

Mosses absorb	282.7 per cent (weight) water
Ferns	259.0 per cent (weight) water
Beech leaves	233.0 per cent (weight) water
Pine needles	150.0 per cent (weight) water
Fir needles	143.0 per cent (weight) water
Rye straw	275.0 per cent (weight) water

The leaves of maple, alder and linden trees and of hazel bushes are valued most highly of all leaves used for bedding. The needles are of little value; they posses little power of asborption, little warmth, are not soft or clean, and may even cause injuries. The mosses have a relatively high value as bedding but low as fertilizer (do not decompose easily). Heather is very hard as bedding and does not readily absorb water; its value is therefore very slight. If litter is constantly taken from the woods this is more or less detrimental to the forest.

4. Sawdust and Excelsior

Sawdust possesses a high power of absorption (357 per cent according to Britenlohner), which is, of course, dependent upon its own degree of dampness. Its fertilizing value is slight.

Sawdust offers a fairly warm, soft and clean bed. It is sometimes used with straw in cattle stables. It is also suitable for use in horse stables if covered with a layer of straw to prevent the sawdust from packing into the hoofs. In stables in which foals are allowed to run loose it is not practicable because of the dust it creates.

Excelsior is a valuable, soft, warm, clean bedding material that possesses great power of absorption (280-440 per cent, Claszen), but little fertilizing value, and is very expensive.

5. Peat, Tanbark, Etc.

Peat is best for bedding when taken from the upper moors (Hannover, Oldenburg, East Prussia), and less good from the lower moors (Holland), since the peat is torn apart on a shredding machine and freed of the finer particles of turf dust by sifting through a sieve. Good peat bedding should be dry, have long fibers, and be fairly free of dust. The lighter colored peat of the high moors is preferred. Darker, more pulverized peat has less power of absorption. The capacity of peat for water is very great (600 to 1,100 per cent by weight). It is furthermore distinguished by readily binding with volatile ammonia compounds (Arnold). In this respect it is very suitable for bedding and is used in horse and cattle stables, less often in sheep and hog stables. Peat bedding is used in a depth of 15 to 30 centimeters (6 to 12 inches) in horse stalls, and the standing place is inclosed by a board 15 centimeters in width. The manure should be removed daily and the bedding that is very wet should be removed and replaced with dry peat. The amount used daily averages 2 to 2.5 kilograms. The opinions expressed by veterinary authorities concerning good peat bedding are usually very favorable.

The same course is generally pursued in cattle stables, or the manure is left lying, which, of coarse, is not to be approved of hygienically. Five to eight kilograms of bedding should be added daily and the stall should be cleaned out entirely after a relatively short time.

About 2.5 kilograms of bedding per head should be given sows and hogs kept for fattening; about 200 to 300 grams should be added daily, and after a month or so it should all be cleaned out thoroughly. Peat bedding is least suitable for hog stables, since the animals root about in it too much.

A daily removal of the manure is also advised in hog stables for sanitary reasons.

Maggi recommends a mixed litter with peat as a foundation and straw as the cover.

Tanbark (which has properties similar to those of peat), peat dust

(too fine and dusty), sand (especially in sheep stables and when there is a dearth of bedding) and humus soil are seldom used for bedding. In using tanbark care must be exercised that it contains no lead. Tanbark that contains lead has been known to cause lead poisoning among horses.

It is dangerous to use cinders on the floor even if covered with a layer of peat or straw. Betheke reports that fatal cases of colic have resulted from the consumption of particles of cinders.

All materials used for bedding purposes should of course be dried well before being used.

IX. Feed Boxes, Mangers and Racks

Feed boxes, mangers and racks must be included in the equipment of the inside of a stable.

Feed boxes should be impervious, smooth, easy to clean and disinfect, wide enough, durable, and constructed in such a manner that the animals can not injure themselves. Those that meet these requirements most satisfactorily are the enameled ones, cast-iron (especially for horse stables) glazed and clay (especially for cattle and hog stables). Feed boxes

Fig. 202. Correct shape of iron manger. *a*, **Manger from above;** *b*, **cross section;** *c*, **longitudinal section.**

made of cement that resists acid are very good; on the other hand, poor cement is affected by the lactic acid and acetic acid contained in certain feeds. The same is also true of feed boxes that are built of hard, glazed bricks that are set in cement and often coated with a layer of cement to give them a smoother surface. There is no objection to the polished granite feed boxes that are sometimes used in the stable of fancy horses; they are of course very expensive. Feed boxes made of polished marble are not so good, since they can not resist the attacks of the acid in bran mash. Those made of hard, well-smoothed sandstone are better; however, if the material is soft and porous, liquid constituents of feed will penetrate and thus make a thorough cleaning and disinfection difficult. Besides this, the animals wear off their incisors on the rough surface. Wooden feed boxes are to be rejected entirely. They are porous, difficult to clean, can not be disinfected thoroughly, and are less durable. They furthermore induce the animals, especially horses, to nibble and gnaw at them during idle hours and thus even cause hiccoughing. If the edges are covered with sheet iron to make them more durable the animal can injure its mouth, nose, etc., if the rims are not fastened on properly or have become defective. They can be used best for feeding sheep dry feed and are used for this purpose very generally.

All feed boxes, no matter of what they are made, should be wide enough, particularly at the top. This is often neglected with feed boxes for horses.

The harder the material the more should this precaution be observed. The animals should not only be able to get the feed out of the feed box with

Fig. 203-a. Horse manger. (According to K. Berg.)

Fig. 203-b. Individual troughs with opening for neck, high rail and separating bars. (Purebred stables of the Veterinary High School of Dresden.)

ease, but should be able to chew with the mouth in the feed box. If feed boxes made of hard material (iron) are too narrow, the animal will strike its lower jaw on the front edge of the feed box whenever it opens its

mouth, and may thus provoke an inflammation of the periosteum of the lower jaw which may result in proliferation of the bone if the cause is not removed. This striking of the jaw naturally causes the animal pain, as a

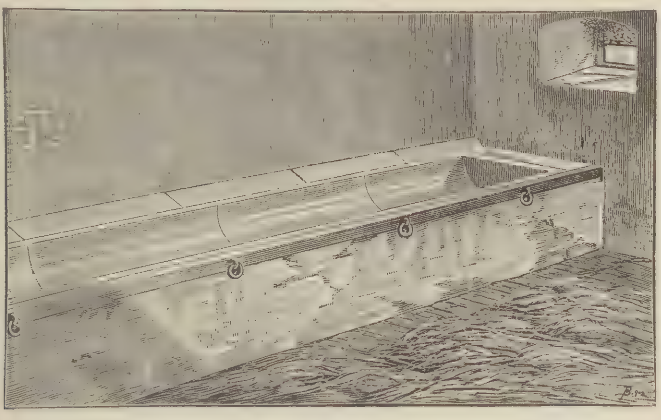

Fig. 204. Continuous manger for cattle.

result of which it draws its head out of the feed box as soon as the feed has been taken into the mouth, in order to chew the feed outside of the feed box. Since horses drop part of the grain out of the mouth while

Fig. 205. Ordinary stable with movable manger.

chewing, that feed which falls to the floor is lost in this case, whereas if the horse chewed over the manger it would fall back into the feed box. A narrow feed box, therefore, is inducive to injuries and to a waste of feed.

The feed box should have neither corners nor sharp grooves, if it is desired that the animals eat everything easily and if a thorough cleaning is

Fig. 206. Stalls for stabling according to Dutch method.

Fig. 207. Position of a calf eating from a low (*b*) and too high (*a*) manger. Both illustrations plainly show the favorable and unfavorable influence on the development of the back and position **of limbs caused by the posture due to the height of the mangers. Notice in figure *a* particularly** the sinking of the back line behind the shoulder and also the unnatural position of the legs. (After Kronacher.)

to be carried out. Feed boxes are much oftener shaped like a trough (Figs. 202 and 203, a and b.) The side walls should be hollowed out somewhat and join the slightly hollowed floor. To avoid injuries, the

upper rim of the feed box is also rounded off, especially on the side toward the animals.

Feed boxes made of one piece are preferable to those made of many pieces set together, because the surfaces join better, easier to clean and no perviousness can arise. The cattle feed boxes in the breeding stable of the veterinary college at Dresden are constructed excellently although expensively (Fig. 203).

Individual feed boxes (Fig. 206) are hygienically better than those running the length of the stable (continuous ones, Fig. 204). They make it possible to divide the feed more exactly and lessen the danger of spreading an infectious disease (tuberculosis).

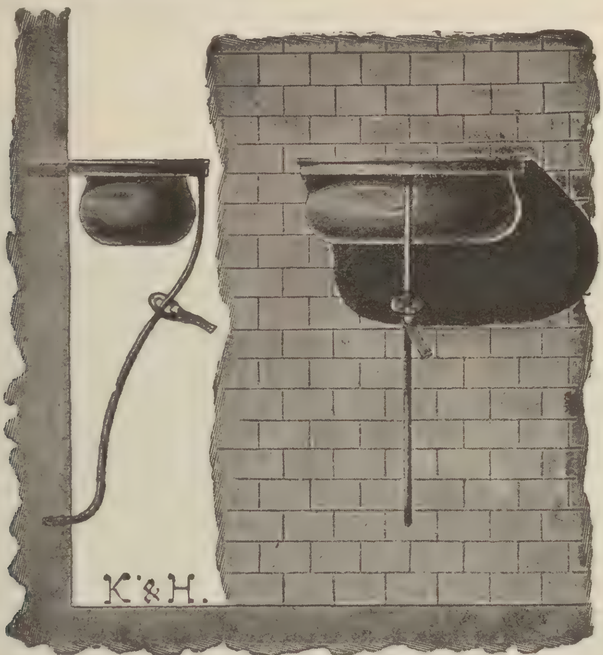

Fig. 208. Free-hanging manger.

The feed boxes are usually attached at a fixed height, but occasionally are hung so as to be adjusted as to height, as in stables used for exercise or in ordinary stables with permanent bedding, especially in sheep stables, or if small and then large animals are to be fed from the feed boxes, or in foal stables, or to prevent crib biting. They are lowered to 30 centimeters (1 foot) when in use, and after the feeding are raised up to the ceiling. Adjustable feed boxes are usually made of wood because of their weight. As has been previously explained, this material is not suitable for feeding boxes.

The fixed feed boxes should be fastened so that no corners or holes are left which are difficult to clean or disinfect, or that serve as breeding

places for all kinds of microorganisms, or as hiding places for mice and rats, and so that the animals can not injure themselves on the feed boxes, and that they can eat comfortably out of them. In horse stalls the mistake is often made of setting the feed boxes too high; indeed, this is done with the idea of forcing the horses to carry their heads high even while in the stable. If this is done the animal is forced to eat with its head in an unnatural position, which brings pressure to bear upon the pharynx and thus makes swallowing difficult, and the flow of blood from the head, especially from the brain, is checked by the pressure on the upper cervical veins (Fig. 207). It is not impossible that frequently cerebral congestion of the blood continuing for some time may produce chronic hydrocephalus (so-called "dummy"). Horses try to avoid the uncomfortable and unhealthful position of the head by removing the head from the feed

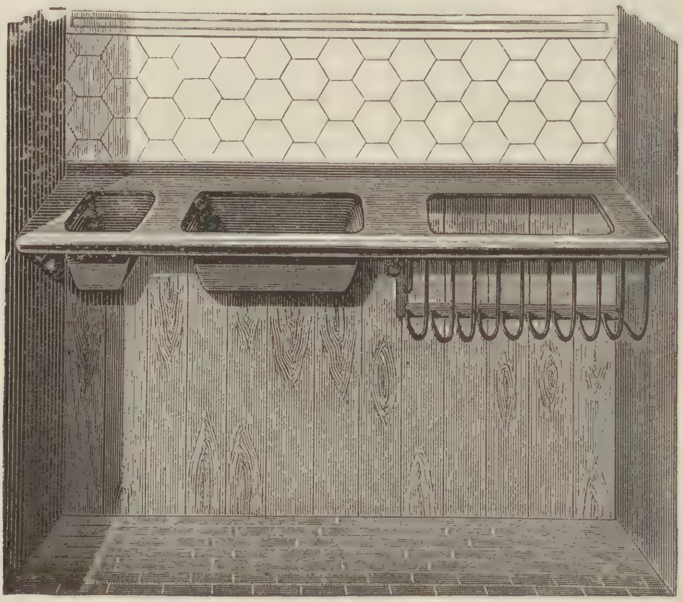

Fig. 209. Feed table with manger and rack for horses.

box with each mouthful of feed, by chewing outside the feed box and thus wasting quantities of feed. The height of the point of the elbow or half the height of the withers is considered the correct height for the upper edge of the feed box. If the feed box is set any lower the possibility exists that the horses might step into it; there are no other objections. For mature cattle a height of 60 to 65 centimeters (24 to 26 inches) is chosen for the upper edge of the feed box. With the Dutch stable arrangement the feed box is set as low as 35 centimeters (14 inches), so that the cattle can stretch their heads and necks over the edge of the feed box when they are standing up or lying down (Fig. 206). The upper edge of feed boxes for sheep is estimated at 40 to 45 centimeters, for hogs 25 to 40 centimeters,

for young animals decidedly lower and for young pigs not over 25 centimeters above the ground.

Feed boxes in horse stalls are sometimes fastened directly on the wall (Fig. 202); sometimes with the aid of simple, horizontal supports they are said to "stand clear" (Fig. 208). In this case the feed boxes must be well rounded off on the outside and have no sharp corners and edges, so as not to cause injuries. To prevent the feed from being scattered the feed box is often hung into a feed table (Fig. 209). It is advisable to brick in under this table (Fig. 210), to prevent the horses from putting their heads under it and the manger or feed boxes, making it possible to injure themselves by jerking the head up suddenly. It is not so satisfactory simply to board up the table (Fig. 211), because that method leaves hollow

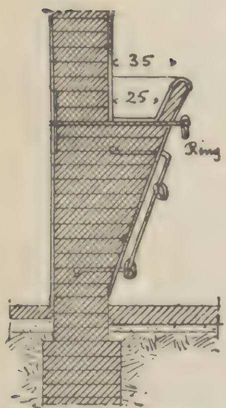

Fig. 210. Solid masonry under manger.

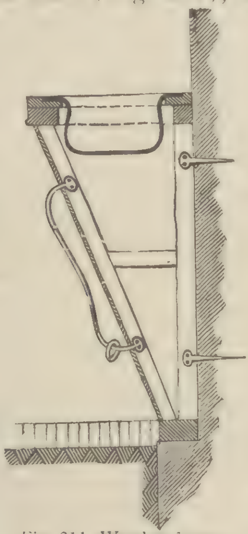
Fig. 211. Wooden framework for manger.

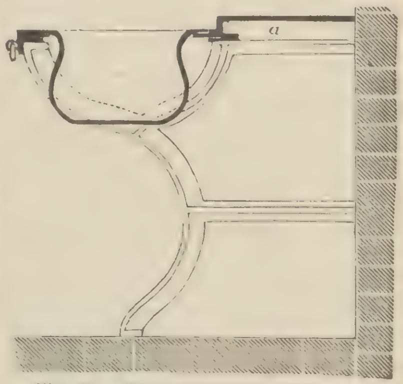

Fig. 212. Iron framework for manger.

spaces which can easily harbor stable vermin (rats and mice) or serve as a place where dust and microorganisms can collect. It is still more objectionable to provide this space with a door to use the space under the feed box for storing bedding, a place for which otherwise is sometimes built under the front third of the stall. Such storerooms for bedding should not be used. Active decomposition processes begin in the bedding that is packed in, filthy with urine and dung; quantities of ammonia are formed, which annoy and irritate the eyes and respiratory organs of the horses whose heads are above the feed boxes. Inflammation of the conjunctiva and of the upper respiratory channels often results. When the space under the feed box is walled or boarded up, the surface that closes it should not be vertical in horse stalls, but should slope toward the wall, so that the bulge of the feed box still protrudes somewhat out from the wall (Fig. 212). This prevents the horses from injuring their knees when they step up close to the feed box.

Feed boxes should be cleaned thoroughly after each feeding, and should be scrubbed out about twice a week with hot water, especially if built of wood. Drinking basins should be treated in like manner. If the cleaning is done thoroughly, slime, which consists chiefly of bacteria, does not develop.

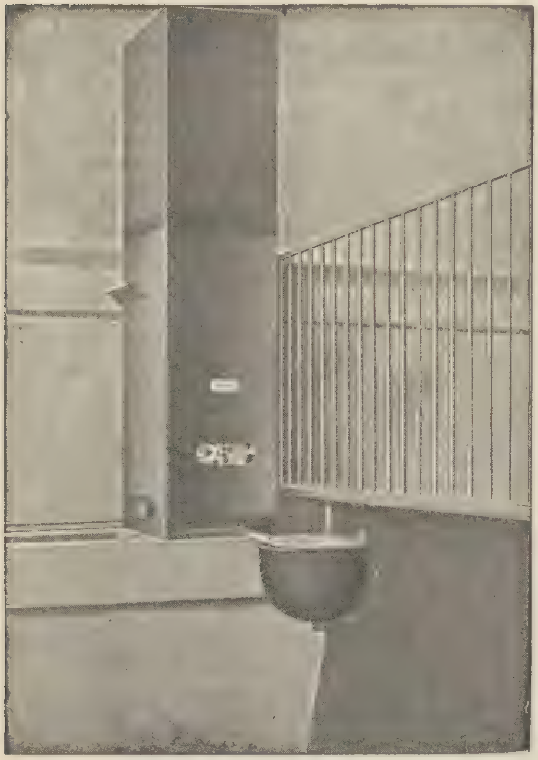

Fig. 213. Automatic feeder for horses. The individual feeder (feeding toward left).

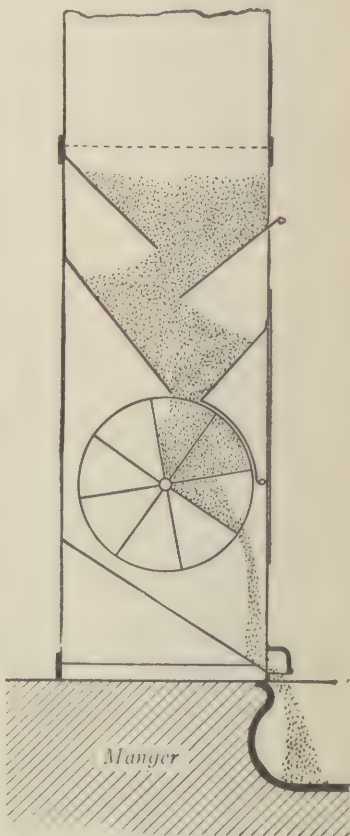

Fig. 214. Automatic feeder for horses. (Cross section through the individual feeder.)

During the last few years G. Schneider of Bielefeld, Germany, has constructed automatic horse feeders which measure off a certain quantity of grain feed at a given time and feed it automatically. The device can be applied in any stable (Fig. 213 and 214). It holds feed for quite a while and gradually scatters the ration of feed into the feed box within a given time, thus forcing the horses to eat slowly and preventing them from breathing on the feed. According to all reports at hand, it works satisfactorily.

The heavy mangers in cattle barns are walled up vertically (Fig. 215). In hog barns they stand directly upon the ground or are slightly raised.

To force cattle and hogs to feed properly, the feed boxes and mangers

are often inclosed in a feed rack or feed grating or bars are built up (Fig. 215-217). These racks or gratings are particularly useful for cattle in

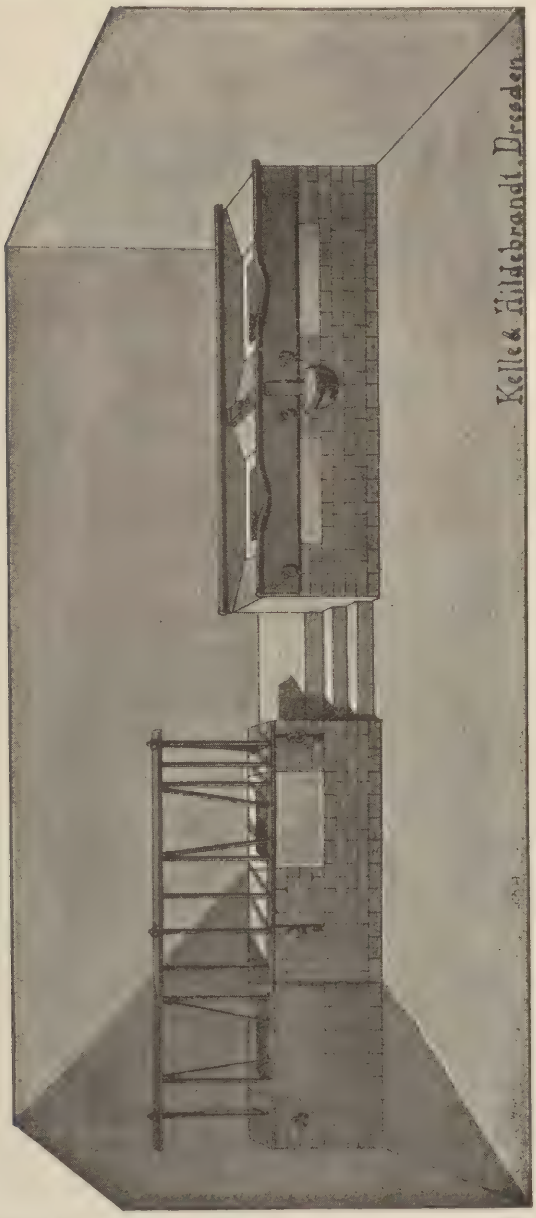

Fig. 215. Cattle mangers.

preventing them from scattering the feed and from robbing one another of feed. In addition to this they prevent the animals from climbing into the feed boxes or manger (Dutch arrangement of stalls, see pages 267 and

292, with low manger.) Furthermore, feed gratings with openings that can be closed are necessary for feeding hot brewers' mash. The mash is first allowed to cool sufficiently in the feed box before the animal is allowed to eat. The construction varies. In large and well-equipped

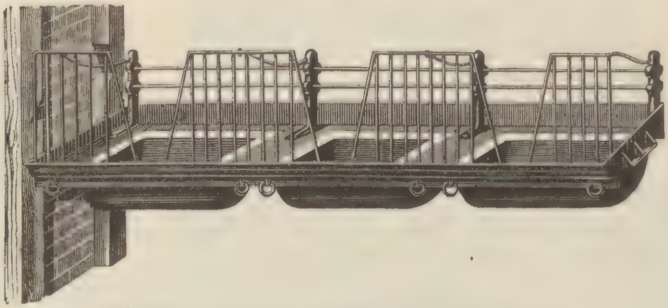

Fig. 216. Iron cattle mangers with feed racks.

Fig. 217. Feed rack with neck latch.

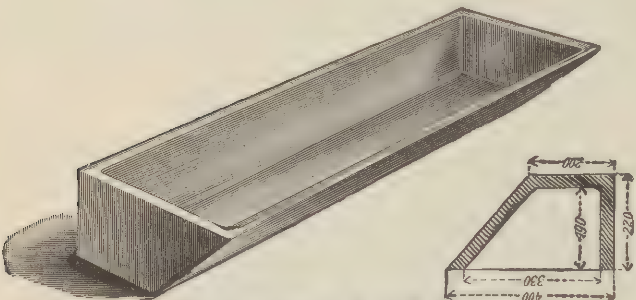

Fig. 218. Hog trough. (*b*, Cross section.)

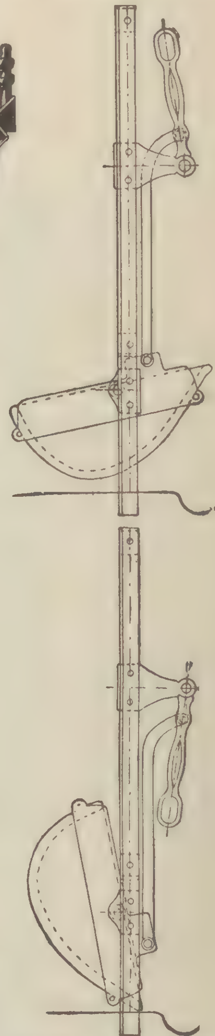

Fig. 219. Tilting trough (hog trough—Janus). *a*, Placed for feeding; *b*, placed for cleaning.

stables wrought-iron feeding bars of various types are often used. The adjustable wrought-iron gratings, which can have all the openings or at least fifty opened or closed easily and quickly at the same time by a simple lever device, are very convenient for stables requiring mash feeding,

etc. If it is desirable to close the feed rack above (Fig. 207) by means of a crossbeam (neck rail), this crossbeam must be kept high enough to prevent the animals from scraping and bruising the upper edge of their necks and developing so-called neck boils or poll evil. Sometimes the front wall of the manger is raised, leaving places cut out for the neck in

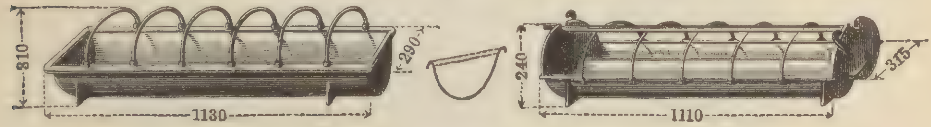

Fig. 220. Feed troughs for pigs.

Fig. 221. Feed troughs.

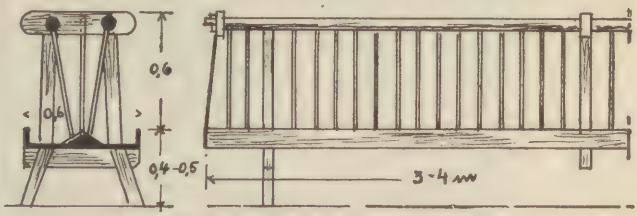

Fig. 222. Double rack (two-sided) for sheep.

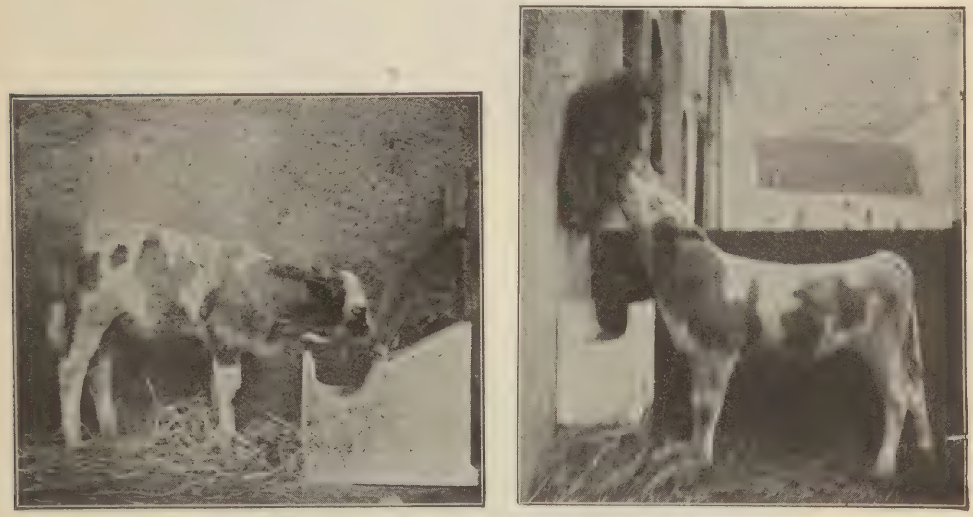

Fig. 223. Position of a calf while eating hay from a table feeding rack (*b*) and from a rack too high (*a*). It is easily seen that as a result of frequently assuming the position shown in figure *a*, marked deviation from the normal will take place in the development of the vertebral column and legs. (After Kronacher.)

place of manger or head bars. This arrangement may be made later by adjusting a heavy oak board with place cut out for the neck.

Hog troughs (Fig. 218), which are best made of clay with a flat, sloping front wall, are sometimes provided with iron gratings which do not prevent the animals from thrusting their heads through but do keep them from climbing in and lying down in the troughs and from crowding one

Fig. 224. Hay rack.

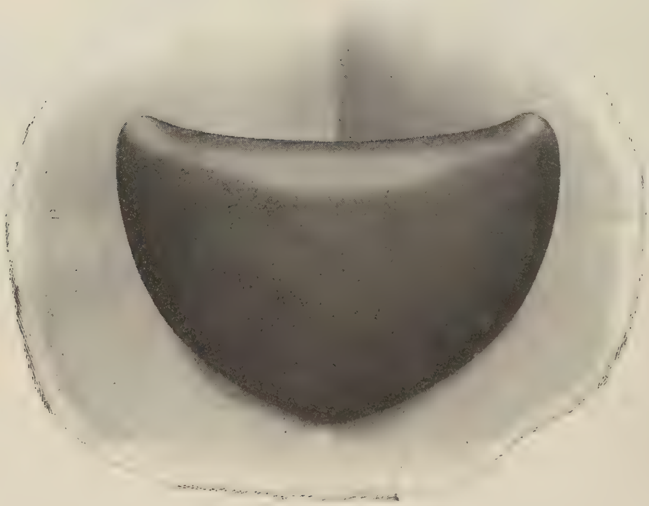

Fig. 225. Cast-iron hay basin.

another away from the feed (Fig. 220). Such devices are to be greatly recommended from a hygienic standpoint, as long as they permit convenient cleaning of the troughs. The same results are also frequently obtained by erecting the trough so that most of it is outside of the pen with only an opening left for the head to be put through. At the same time a cover (lid) fastened on a movable axis is adjusted above the feed trough, by means of which the trough can be closed alternately on the inside or the outside (Fig. 219). This has the advantage of very easily excluding the hogs from the troughs while the troughs are being cleaned and while they are being filled with feed.

An impervious, smooth, and therefore easily cleaned and disinfected material is likewise preferred for the *racks,* even if the material used is not of such great importance as with the cribs. The best material for horse racks is iron; the poorest is wood. The latter is preferred, however, for sheep racks, which are usually built so as to be movable. During more recent times even the sheep racks are built of galvanized iron. All sharp edges of racks and cribs at the height of the sheep should be avoided, to prevent the fleece from being damaged. The rods of the rack should not bulge out too much. Horses may easily bump themselves on racks above the cribs or manger and that bulge out too far.

In sheep stables it is advisable to have the rods of the racks in a vertical position (Fig. 222), to keep the dust and particles of plants as much as possible from falling down upon the wool of the sheep standing below. In stalls for mother sheep round racks (about 1 or 2 meters in diameter) are preferred to the long racks, since in crowding up to the round racks there is less danger of pressure on the enlarged, pregnant body, a frequent cause of premature lambing. With long racks 40 centimeters (16 inches) are allowed per sheep or wether, 30 centimeters (1 foot) per yearling, and 15 to 20 centimeters (6 to 8 inches) per lamb. A flat crib is often adjusted beneath the rack, at a height of about 40 centimeters (2 feet) (Fig. 222). It is put there to catch the feed that falls down, and is also used for feeding turnips, potatoes, etc. The crib should be about 20 or 25 centimeters (8 to 10 inches) deep, with double racks 40 to 60 centimeters (16 to 24 inches). The cribs should be covered with sheet zinc or with galvanized sheet iron to prevent the animals from gnawing at them.

Great care should be exercised not to erect the racks too high. If the racks are too high the animals must raise their necks too high, which causes the back to become concave (Fig. 223). If this happens often with young animals that have a weak, long back, it may result in the development of "sunken back" (sway back). Furthermore, dust and plant bits fall more easily from high racks into the animals' eyes and thus cause inflammation of the eyes. Pieces of plants also fall more easily from high racks into the hair on the head and into the mane while the animals are eating. The dust particles cause itching and provoke the animals to rub themselves and to rub off the halter.

The correct height for horse racks is 30 to 35 centimeters (12 to 14 inches) from the lower edge of the rack to the upper edge of the manger, unless the rack is sunk into a recess at the same height as the feed box or into the feed table beside the feed box, two arrangements that are recommended (Figs. 209 and 224). For full-grown cattle, racks are practicable only with narrow feed boxes; they should be adjusted with the lower edge scarcely 120 centimeters (4 feet) above the floor. Hay basins (man-scarcely 120 centimeters (4 feet) above the floor. Hay basins (mangers) are seldom used (in Germany) instead of racks (Fig. 225), the hay being easily scattered from the former.

Warning is given against painting the feed boxes and racks with red lead (minium) and other paints containing lead. Severe and even fatal cases of poisoning have repeatedly occurred among horses and cattle that have licked off paints containing lead and that had not dried completely.

For information regarding automatic drinking basins see page —.

X. Stabling Methods, Stalls, Tying Devices, Etc.

The *method of stabling* horses is always along the long wall, either on one or both sides, with the head toward the wall. Cattle are often stabled in the same way, but sometimes with their heads toward the middle of the stable and with the hind quarters toward the wall in which case a gangway is kept clear behind the animals. If the stabling is done

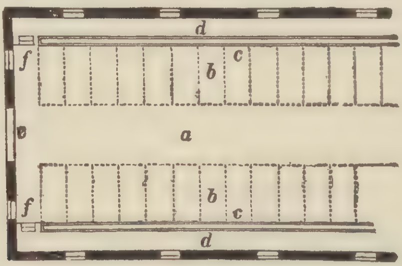

Fig. 226. Stabling in long rows with a common alleyway. *a*, Manure gangway; *b*, straw; *c*, manger; *d*, feed gangway.

according to the first method, the feed boxes or mangers are placed either directly against the wall or slightly away from it, so that a corridor is left open between the wall and the manger, called the feed passage (Fig. 226). Hygienically this last-mentioned method is the best of those that have been mentioned, since it affords the least chance for the transmission of an infectious disease, especially tuberculosis, also contagious pleuropneumonia and foot-and-mouth disease. These diseases are usually transmitted by infectious vapor globules (droplets) which the sick animals cough out; this is especially true of tuberculosis. If the animals stand with their heads directly against the wall, the current of air with the expelled droplets is diverted by the wall in the direction of the neighboring cows. If the cows stand opposite one another with their

heads at a common manger, or if they are merely separated by a narrow feed passage, the droplets can be scattered by coughing to the cow standing opposite and thus endanger that animal. However if the cows stand facing the wall, but are separated from it by a passageway (Fig. 226), then the above-mentioned features favorable for disease transmission, but only these, disappear, and the danger of infection is materially lessened. Hygienically it is most advantageous to stable cattle in cross rows, one behind the other, with the heads all facing in the same direction (Fig. 227). This method also has the advantage of providing better drainage for the liquid manure.

The *stalls* of cattle should not be *partitioned* off by walls. Only bulls are occasionally separated from one another. In municipal bull stables narrow passageways are left between the separate stalls that are parti-

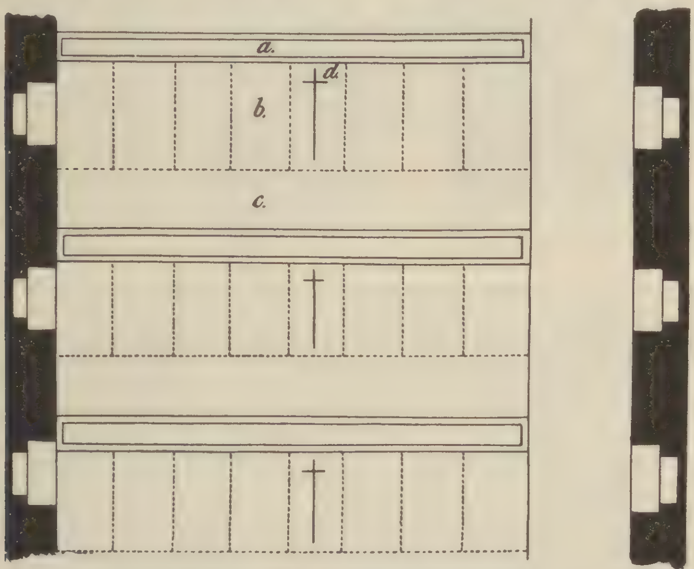

Fig. 227. Stabling in cross rows, one behind the other. *a*, manger; *b*, stall; *c*, manure and feed gangway; *d*, head of the marked animal.

tioned off so that the attendants can seek shelter there while feeding and cleaning and not be pressed against the wall or the stall bar. In foreign countries (Belgium, etc.) I have often seen the front part of stalls in cow barns divided off by a partition wall 1 to 15 meters in height and about 1 meter deep (Fig. 231). The main object is evidently to keep the cows from eating one another's feed. If the partitions are built somewhat higher and deeper they would also check the transmission of tuberculosis.

As a rule horses are separated by partitions. Occasionally the partition is omitted with horses belonging to a team. The purpose of partitions is, of course, to prevent the animals from injuring one another. Partitions are absolutely necessary for animals that are in the habit of

stealing feed from their neighbors, and for excitable (menstruating) and spirited horses.

Complete separation and a removal of all danger of injuring another is accomplished by erecting wooden partitions between the stalls to a

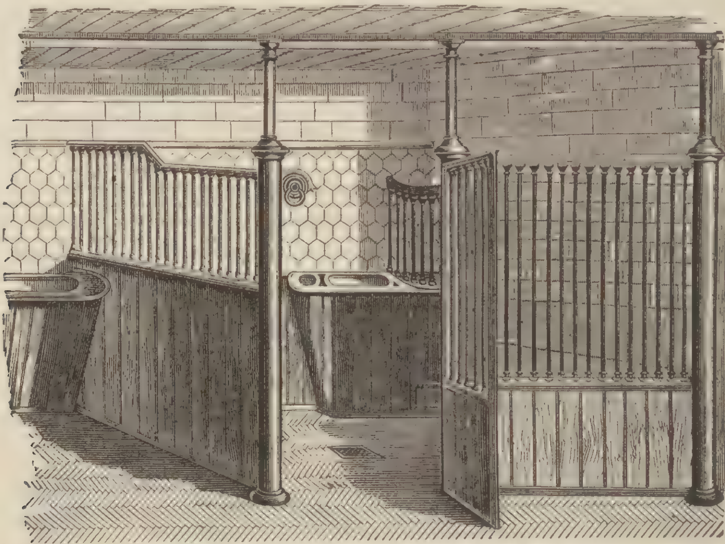

Fig. 228. Horse stalls and horse box stalls.

height of 2 meters (2¼ yards) in front and 1.3 to 1.5 meters at the back (Figs. 228 and 229); i. e., constructing so-called box stalls. With horses that kick, the back of the partitions, as well as the pillars, are

Fig. 229. Partition with additional grating over one-half of the length.

padded with straw or seaweed to avoid injuries. The movable, separating stall bars (Fig. 232) which are fastened 1 meter above the floor are simpler and cheaper than partitions and also take up less room; but they give no absolute protection against horses that kick. The stall bars,

which are best made of wrought-iron pipe 7 or 8 centimeters (3¾ or 4 inches) in diameter, closed at the ends (they are less satisfactory if made of smooth, round lumber 10 to 13 centimeters in diameter are fastened

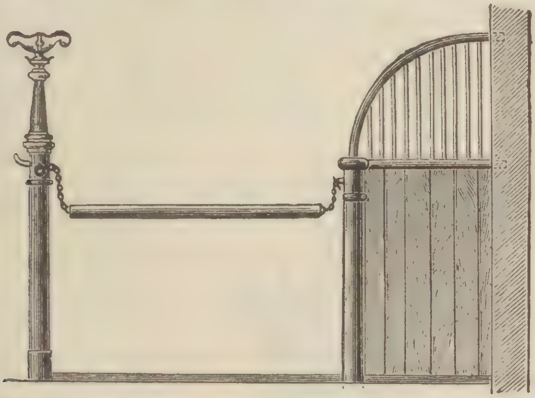

Fig. 230. Separating stall bar in connection with a short partition. On the bar is a movable cast-iron harness rack.

in front to the manger and hang in back either from the stall posts (Fig. 230) or from ropes or chains hanging from the ceiling (horizontal bars; Fig. 232). This device is to be fastened so that it can be easily released

Fig. 231. Open cow and calf stable with partitions between the individual stalls.

at any time, even with the weight of the horse resting on it which occurs while kicking over the stall bar and while riding it without first lifting the stall bar, and so that it will automatically release itself where the stall bar is fastened to the pillar when the bar is lifted upward. This last

requirement is necessary so that if horses, when rolling, get under the stall bar, they will not injure themselves when they get up quickly. The best method of fastening of all that are recommended for this purpose consists in hanging the stall bar by means of a wide iron ring on a long, movable hook which is held fast by a ring that is slipped over hook (Fig. 233). When the beam is lifted upward it also forces the ring upward and the beam unhooks itself. In case the animal is astraddle the beam the ring need only be shoved upward; the hook hangs down and the beam

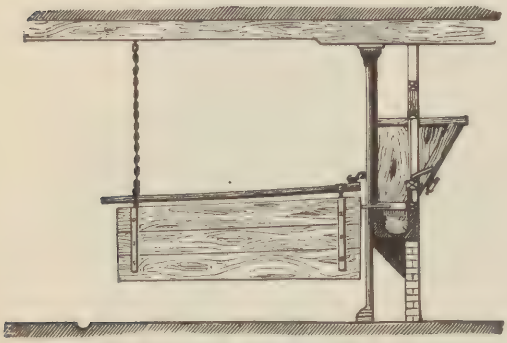
Fig. 232. Separating stall bar with board wall.

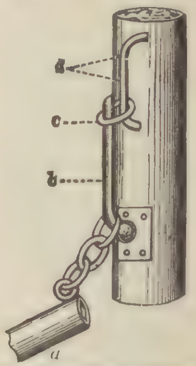

Fig. 233. Fastening arrangement for stall bar.

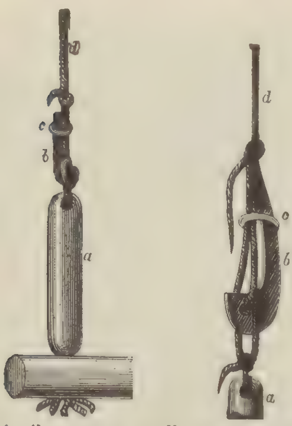

Fig. 234. Suspensory appliances for stall bar.

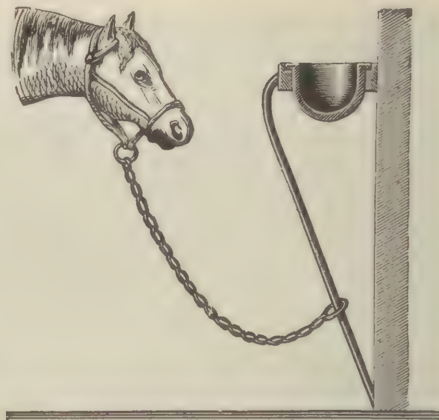
Fig. 235. Tying device for horses.

falls to the ground. Fastening with chains and ropes is accomplished in an analogous way, excepting that in that case the automatic release is missing (cf. Fig. 234). Furthermore, care should also be taken that the stall bars as well as the board partitions are smooth (not splintery), to prevent the tail hairs from catching and being pulled out.

To complete the protection that stall bars are supposed to afford, they are often bound or covered at the back part with straw or straw mats, or movable board walls are applied (Fig. 232). It is not practicable to

cover the stall bar with tin, since the tin mounting can easily cause injury if it is put on badly or has become defective.

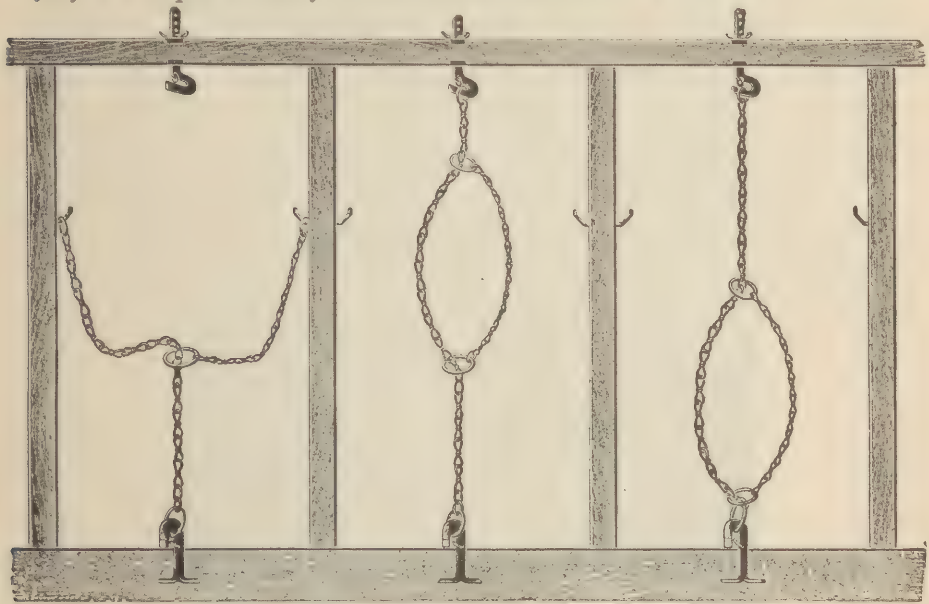

Fig. 236. Grabner's Hanging chains.

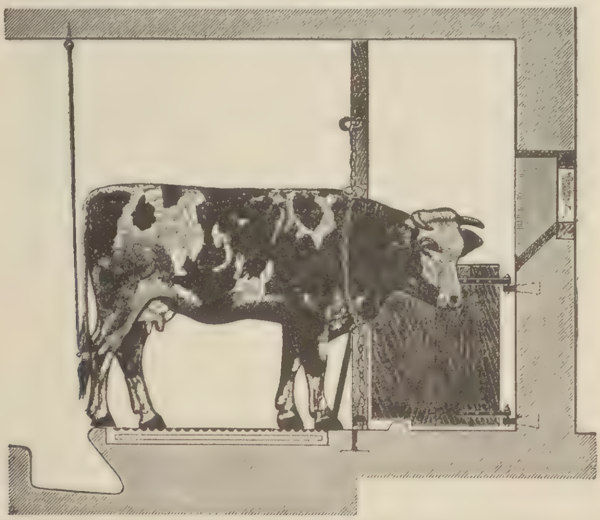

Fig. 237. Cross section of an improved cattle stall with Grabner's hanging chains (chaining method) and feed door.

Matúred horses and cattle are usually tied in their stalls, especially to save space, to avoid injury from one another, to facilitate cleaning and attendance, and to make possible a more exact division of feed. Few demands are made from a hygienic point of view with regard to the

tying devices for cattle, the head and neck chains (stanchions). With the use of head chains for cattle, care should be exercised that the chains placed about the horns are not drawn so light as to cause bruises and boils at the root of the horns. To prevent restless bulls from scraping their necks broad leather straps are often placed under the neck chain (Fig. 238), or the stall chains are fastened to heavy leather neckbands. In the short Dutch stalls the cows should be prevented on the one hand from stepping too far forward and from discharging urine and feces in this position on the floor of the stall, thus soiling the animals, and on the other hand from stepping too far back and then lying with their hind quarters over the broad, deep manure gutter. To prevent both, and for other reasons, it is advisable to use the Grabner hanging chain (Fig.

Fig. 238. Protection against rub wounds on the neck.

236 and 237). This also has the advantage of being durable, easy to unhook in case of fire, and of annoying the animals very little. Devices for unfastening the animals are explained by Figs. 240-242. The device shown in Fig. 241 is suitable for unfastening many animals at one time in case of fire.

With regard to the method of tying horses, it is necessary to guard against the horse stepping or kicking over the chain when it becomes loose, namely, when the horse steps up to the manger, which can result in wounds from chafing and in falls which may cause severe injuries. Stepping or kicking over the chain may be prevented most easily by tying the horses comparatively short, or by a wide ring which slips over

Fig. 239. Tying device with a halter strap lead. (After K. Berg.)

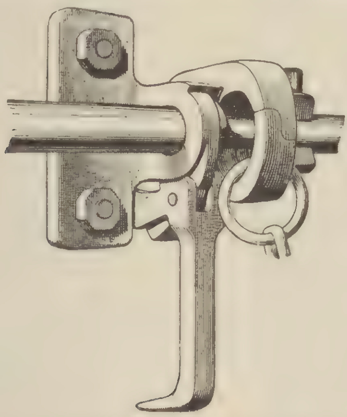

Fig. 240. Lohr's uncoupling (or tying) device.

sound iron rod that runs from the middle of the feed box downward (Fig. 235). A better method of fastening is by one or two chains or straps which pass over a pulley-like roller fastened in the middle of the feed box,

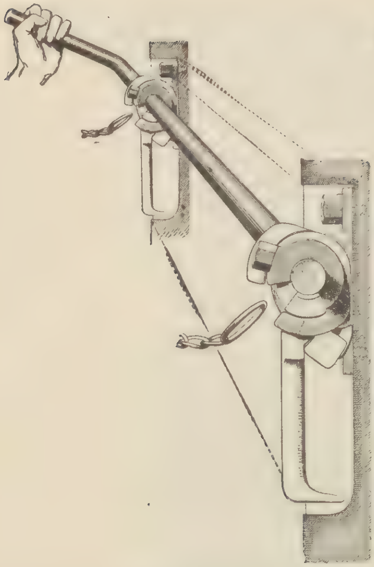

Fig. 241. Uncoupling device for more than one animal

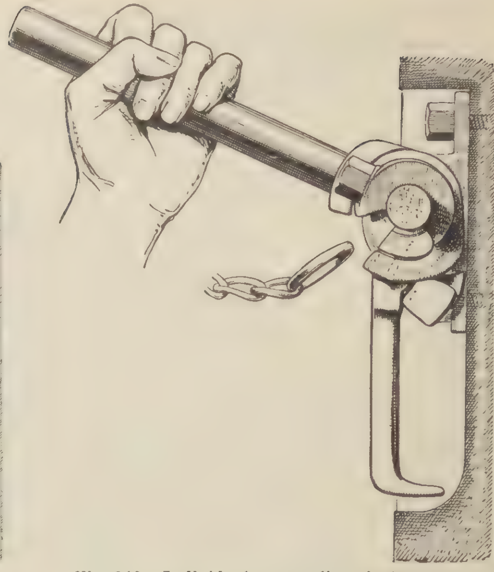

Fig. 242. Individual uncoupling device.

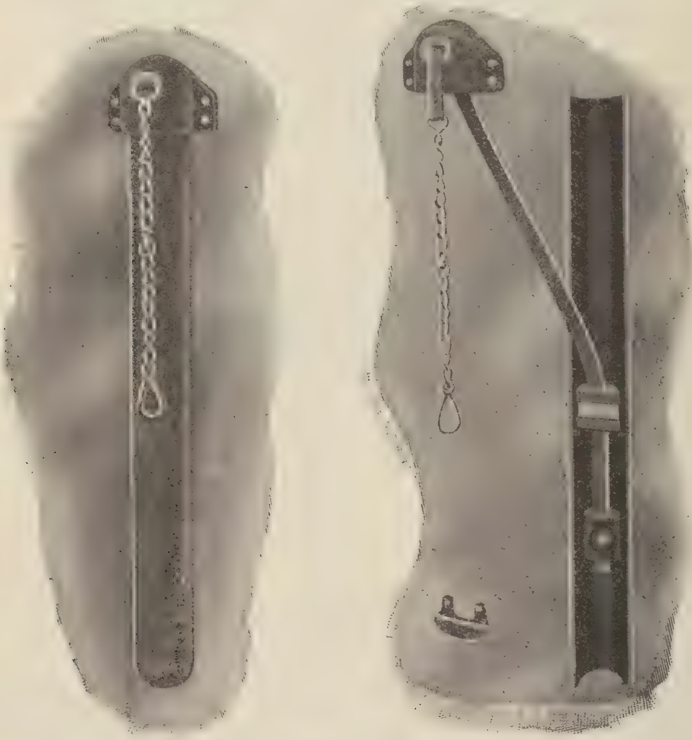

Fig. 243. Tying device. (After K. Berg.)

or over one fastened to the right and to the left on the feed tables or manger and which are constantly kept taut by light counterweights (Figs. 239 and 243).

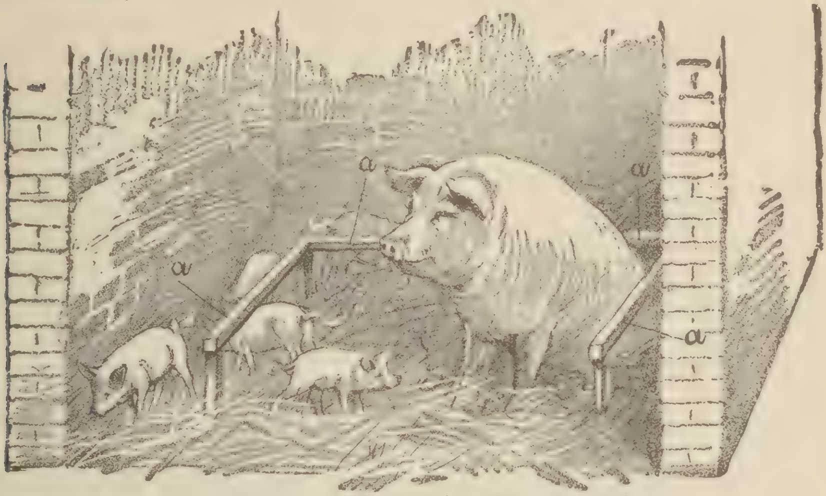

Fig. 244. Hog pen with protective railing (*a*) for pigs.

The larger domestic animals, especially pregnant mares and convalescing animals, are seldom allowed loose in the stall, though foals and calves are often left so, and sheep and hogs always are. Compartments for horses are called *box stalls* or *exercising stalls*. Generally one box stall

Fig. 245. Hog stable arrangement.

is allowed each animal, to avoid injuries from their kicking and biting one another. In large studs several horses up to the age of three years are often allowed to run about loose in large stalls and are tied only during feeding time. Few disadvantages arise. Stabling in box stalls is hy-

gienically far better than tying the animals in the stall, since the former permits a free though limited moving about. The box stalls, however, require too much space, and this is the chief reason why they are not used more. A box stall should be about 3 to 3.5 meters (3¼ to 4 yards) square, and is divided off by a partition about 2 meters in height, which is most practicable if the lower half is made of masonry or wood and the upper half of iron grating (Fig. 228). If several foals are to be stabled in one box, 5 square meters should be allowed per head.

The partitions for calf stalls or pens and for hog pens should be about 1.3 to 1.5 meters in height. Pumice stone concrete, masonry of spongy stone or of hollow bricks, or heavily galvanized corrugated iron, are used for the partitions. Solid partitions are better than those made of iron rods, because the animals are disturbed less and are protected better against drafts and contagion. In order to inclose the side of the pen toward the passageway, iron gratings are used (Fig. 245). Lead paints should not be used in painting the iron gratings or posts, because they may cause lead poisoning if the animals lick them. With regard to the size of pens for calves and hogs, see page 255.

The stone walls of the pens that have been referred to are easily cleaned and disinfected, but have the great disadvantage of being cold and of easily causing colds, diarrhea, etc., especially among young pigs. In recent times they are not being used so much and the wooden partitions are again in demand.

In hog pens used for breeding purposes it is advisable to adjust an iron rod entirely around the pen 25 centimeters (10 inches) above the floor and at a distance of 25 centimeters from the wall, to prevent the young pigs from being crushed (Fig. 244).

At long intervals of time a general, thorough cleaning of the stall should be carried out, with the removal of the dung. The racks, feed tables, mangers and feed box, floor, walls, pillars, etc., should be scrubbed with hot lye. In addition to this the walls and ceilings should be repaired and whitewashed or painted once a year.

XI. Temperature of the Stable

In the interests of hygiene and production it is necessary that the stables be kept at the right temperature. For this purpose every room of the stable should be provided with a thermometer. For protection the thermometer should be set in a wooden frame (Fig. 246) and sunk into the wall. To facilitate control of the temperature, the degrees within which the temperature of the stable is supposed to vary should be marked conspicuously. The temperature of stables should be kept within the following limits:

The average stable temperature for horses is 15°C. (59°F.), with a range of 10 to 17.5°V. (40 to 63.5°F.); for nursing mares, young foals, tender skinned, purebred horses, 17.5 to 18.5°C. (63.5 to 63.3°F.); for

cattle, 12.5 to 17.5°C. (54.5 to 63.5°F.); for milk cows and calves, 15 to 17.5°C. (59 to 63.5°F.); for fattening and work animals, 12°C. (53.6°F); for sheep, 10 to 12.5°C. (50 to 54.5°F.), but after shearing and at lambing time 16 to 17.5°C. (60.8 to 63.5°F.); for hogs, 12.5 to 15°F.), but for nursing sows, young pigs and lean shoats, 15 to 17°C. (59 to 62.6°F.). During recent times attempts have been made to keep foals and young stock at a temperature of only 10 to 12°C. (50 to 54.5°F.) in order to harden them. If this is done, however, care should be exercised to keep the stable dry, the air fresh, the bedding clean and the food nourishing.

Too great a deviation from these temperatures, either lower or higher, has very disadvantageous results. A stable that is too cold causes a loss of feed with hogs and herbivora under ordinary conditions, to the extent that the amount of heat which is created by the vital processes and especially by the digestive process is insufficient to heat the body adequately in a cold shelter. To produce heat more food must be consumed which in a warmer stable would be saved or used productively. On the other hand, the work of digestion with a highly nutritious feed takes place in ruminants with so much production of heat that sufficient heat is created to keep the body warm even in a cool stable. A cool stable, therefore, allows a complete ultilization of feed when using a highly nutritious feed. A moderately cool stable is desirable even with a highly nutritious feed in order to cause sufficient body heat to be given off. Furthermore, the appetite is better with a lower surrounding temperature; animals that are being fattened consume larger quantities of feed; they can therefore be fattened more quickly with intensive feeding. For this reason cattle that are being fattened in North America by intensive feeding have recently sometimes been kept in half-open stables during the cold time of the year with good results. The old belief that keeping animals in cold stables denotes a waste of feed can no longer be accepted.

A stable that is too cold, and especially one that is also damp, may cause colds (catarrh, digestive troubles, rheumatism) among young animals (young pigs, etc.) and among draft animals that return overheated from their work. Too high a temperature is often found in low, poorly ventilated, filled or even overcrowded stables (cattle barns). Through ignorance the doors, windows, ventilating apertures and all grooves and cracks are carefully sealed during cold weather so that no draft can enter and the temperature will not drop. The air in such a stable is very damp and hot. Under such conditions the animals have trouble in giving off sufficient heat, which can readily be detected by the rapid, superficial breathing and the frightened or anxious look. Such a damp, hot stable is of no benefit to the owner, but only causes harm. An abode that is too warm combined with great humidity does not effect a saving of food but a waste of it, since too much work must be accomplished to produce the proper loss of body heat. In addition to this, the general condition and the efficiency (muscular work, milk secretion, deposit of

fat) suffer from the loss of appetite produced by the high temperature. Furthermore, the animals become flabby in the hot, damp air, more susceptible to drafts and more receptive toward diseases. Finally, the high temperature favors the development of microorganisms and even of causative agents of decomposition and disease; with consequent increase in the pollution of the air and in the possibility of infection. Bang, the well-known investigator of tuberculosis, reports that tuberculosis is especially destructive to cattle in hot, damp stables.

Fig. 246. Stable thermometer.

Fig. 247. Cockroach, *Blatta orientalis*. (To left male and to right female with extended egg capsule.)

Every owner of animals is particularly advised to regulate the temperature of the stable by the thermometer. Regulating the stable temperature should not be done according to the sense of feeling but according to a reliable thermometer hung in every stable.

With a high stable temperature and a low outside temperature the stable temperature can easily be brought to the desired degree by proper ventilation. With a low outside temperature it is more difficult to raise the temperature of large stables that are not fully occupied, if, as is usually the case, there are no stoves nor other artificial methods of heating. Under such conditions it is advisable to limit the artificial and natural ventilation (putting up double doors, making the doors and window frames air-tight with straw and tow, closing the ventilating

aperture, etc.); then an effort is made to lessen the heat radiation of the stable by heaping up bedding material against the outside of the outer walls, by covering the inner surface of the walls with mats, especially on the side from which the prevailing winds come, and above all to decrease the loss of body heat of the animals by means of abundant bedding and to increase their body heat development by giving plenty of nourishing feed. The stable temperature can also be raised by artificially decreasing the size of the stable by making a low ceiling of poles covered over with straw. It ought not to be difficult to manage in general without special measures, if the stable is completely occupied and if it is constructed according to the principles mentioned above. Hygienically a cool stable with good air is decidedly preferable for large domestic animals to a warm, damp stable. Young animals, especially pigs, should not be kept in a pen that is too cool. Hogs that are being fattened should also not be kept constantly in a cold shelter, as the fat in the bacon may become too soft and rich in oleic acid.

We are powerless, however, to lower the stable temperature during the hot times of year. We often try in vain to produce a slight breeze and to give the animals relief during sultry summer days by opening doors and windows for abundant ventilation. Even sprinkling the stable passageways and stalls with cold water is ineffectual under such conditions[9]. The direct rays of the sun may be diverted from the windows by means of Venetian blinds, shutters and curtains attached on the outside. Finally, it should be remembered that thick, hollow walls conduct the heat more slowly and to a less degree than thin, solid walls (see pages 260-261).

XII. Stable Vermin

The most numerous and troublesome stable vermin are the *flies*. Of these the biting flies (e. g., in cow barns *Stomoxys calcitrans*) are especially to be mentioned. The nutritive state of the animals, their efficiency, draft work and fattening quality as well as milk secretion suffer through the continued annoyance of these pests. A method for the radical annihilation of flies is not yet known. To combat the fly plague the following points besides extreme cleanliness must be considered:

1. Means of catching and killing flies. Among these should be mentioned caterpillar torches, sticky substances on paper (fly paper); sticks painted with fly glue, which should be scraped off and reapplied frequently, etc. A suitable sticky substance may be made by melting together 2 parts of colophonium, 1 part of venetian turpentine and 1 part rapeseed oil. To 3 parts of this mixture add 1 part of beet (sugar)

[9]The amount of heat required for the evaporation of 1 liter of water amounts to 580 calories. If a considerable cooling off is to be accomplished 5 to 10 liters of water must be evaporated within a relatively short time even for small rooms. However, in doing this the air would become charged with water vapor which would again considerably disturb the normal loss of body heat and thus the desired results would not be obtained.

syrup. There are also the insect powders, fly swatters and fly rollers, fly poisons (e. g., sugar that has repeatedly been moistened with 7 to 8 per cent formalin solution), or bowls with formalin-milk (two tablespoons of formalin to ½ liter of milk) into which a thin slice of bread is occasionally laid, fly traps, and last but not least, also the swallows. The nesting of these birds may be encouraged by nailing small boards under the beams of the stable.

2. Methods of getting rid of flies by creating unfavorable living conditions. Dim light, e. g., stable windows of blue glass or painted blue (milk of lime with bluing), or painting the walls blue twice a year (100 liters of water, 5 kilograms of slaked lime and 500 grams of bluing); drafts, by opening the windows and upper wings of doors and at the same time hanging dark, porous sacks over the openings; painting the walls with repellant substances (alum—1 pound to 1 pail of milk of lime, formalin, creolin—150 grams to 12 liters of pyrolignite of lime, petroleum, carbolineum or creosote oil).

Attempts are often made to kill the flies with the so-called fly rollers after dark while they are sitting quietly on the ceiling. In recent times a commercial fly oil has been recommended for combating the fly plague, especially for horses. The odor is not supposed to be offensive. However, its effect does not last long (1 to 2 hours).

A mixture of 1 part of fresh, undecomposed laurel oil and 10 parts of linseed oil, or 1 part of laurel oil, 4 parts of diluted spirits and 5 parts of olive oil, is supposed to have a more lasting effect.

Rats prefer to nest in hog pens, *mice* in horse stables and in hay lofts. They not only annoy the occupants of the stable but rats are even said to attack pigs, while on the other hand horses often either refuse or dislike to eat feed that is soiled with feces and urine of mice. Rats, which according to tests are about 8 per cent trichinous, can, if they happen to be harboring intestinal trichinæ, discharge a large number of young trichinæ larvæ with their feces into the hog pens and feeding troughs and thus transmit the disease trichinosis to hogs. Rats may also spread foot-and-mouth disease, bubonic plague, mange, etc. A rat eats in a year more than a dollar's worth of feed. As many as 100 rats often exist, even on smaller farms. One mouse eats per year about 3 pounds of wheat, rye, barley, oats or corn, or about 4⅓ pounds of bread. One pair of rats produce 150 descendants (two generations) in one year, one pair of mice as many as 270 (three generations).

To combat the mice and rat plague it is advisable first of all to eliminate all hiding places (litter rooms, hollow bridges, covered sewers, etc.). The surest destroyer of house and field mice, and also the least harmful to other animals and to people, and furthermore the cheapest, is Loeffler's mouse typhus bacillus. The bacterial preparations that are recommended for the extermination of rats are up to the present time still very unreliable and rather dangerous for people and farm animals.

This latter statement is also true of the phosphorus, arsenic and squill preparations which are often used with good results for the extermination of rats. A mixture of equal parts of flour and sugar with double the quantity of gypsum is supposed to kill rats. If conditions permit, good results can be obtained with poisonous gases (SO_2, CO, HCN) as well as with specially constructed large traps. An important condition of any lasting results is the simultaneous and uniform action of the property owners, municipalities and owners of fields around the villages that are overrun with the rodents. The natural enemies that help to destroy rats and mice are cats, dogs, barn owls and big weasels.

If pigeon cotes or chicken pens (or swallow or sparrow nests) are built in the stables, there is danger of *bird mites* (*Dermanyssus avium*), which fall down at night upon the animals standing below and bite them and make them restless. Small, slightly scabby, itching nodules result on the upper (dorsal) part of the neck and back, especially with horses. If it is desired to see these parasites it is advisable to lay a white woolen cover on the animals and to examine it upon removal in the morning. The red mites, that are barely visible to the naked eye, can then be seen quickly crawling away. These mites are also said to crawl into the external auditory canal of cattle and there cause local inflammation and severe irritation. To avoid these difficulties the bird pens and nests should be removed from the barns. The bird mites, the numerous chicken fleas and the various species of lice in the chicken and pigeon coops can be exterminated by fumigating with sulphur, by disinfecting with formalin, or by washing off the walls, ceiling, floor and roosts with hot lye, after first giving it all a thorough mechanical cleansing or a coat of milk of lime. During the fall cleaning of the pigeon houses the straw is often sprinkled with aniseed oil to destroy the mites[10].

Cockroaches (Fig. 247) and crickets are destroyed by means of a potato or pea mash (3 parts of the mash to 1 part of a mixture of 2 parts borax to 1 part salicylic acid or insect powder) which is laid out at night. Grooves and cracks should be sealed with cement whenever possible.

Insect powder is used for exterminating fleas, and the floors are scrubbed with a hot soft soap or cresol soap solution (1.5); kerosene is often added when especial attention should be paid to the grooves and cracks. Fumigating with sulphur is also good.

XIII. Dog Kennels

Watchdogs are generally provided with a kennel, while house or lap dogs and larger fancy dogs and stable dogs are given a bed on a blanket or in a basket lined with a blanket, on a mattress, mat, bag of straw or wooden floor rack (Fig. 248) placed in the room, in the hallway or

[10]For further information on mites and lice on poultry, see Farmers' Bulletin 801.

in the stable. Hunting dogs and terriers are usually kept in a cage.

The dog kennel should (1) offer protection against the wind, the

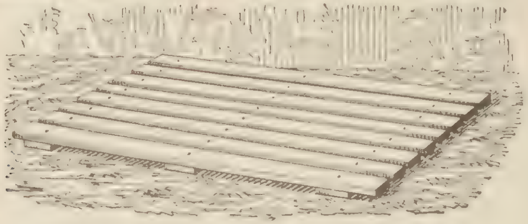

Fig. 248. Wooden platform or lattice for dog.

heat of the sun and against rain; (2) be warm enough in the winter, and (3) be built so that it can be cleaned easily and thoroughly.

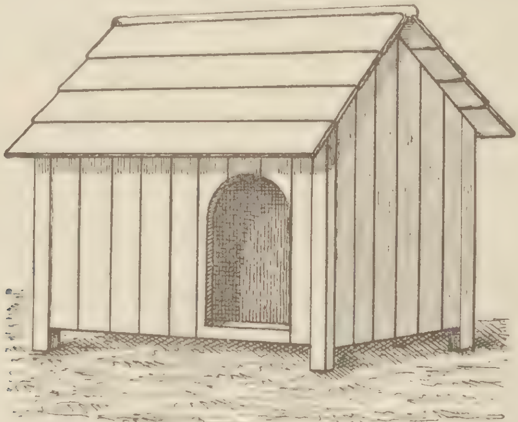

Fig. 249. Dog kennel with side entrance.

The first requirement can be met by a situable construction of the kennel. The entrance should not face in the direction of the prevailing

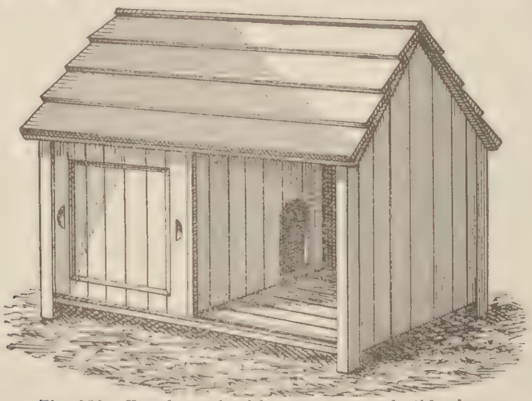

Fig. 250. Dog kennel with anteroom and slide door.

winds. It is advisable to have it on the long side, not on the front (Fig. 249).

To have a kennel warm and dry it should be built of wood and be of a size suitable to the dog. It should be large enough so that the dog can just stand upright in it and can lie down with the legs stretched out. The kennel should have a waterproof roof and be placed on short legs so that the floor does not rest upon the ground. A bedding of straw, etc., can be put in, and this should be more abundant during cold, rough weather. To prevent rain from driving into the kennel it is well to provide a passage as entrance (Figs. 250, 251). The sliding door of the kennel (Fig. 250) makes it possible to use the two sections interchangeably as kennel room and passageway.

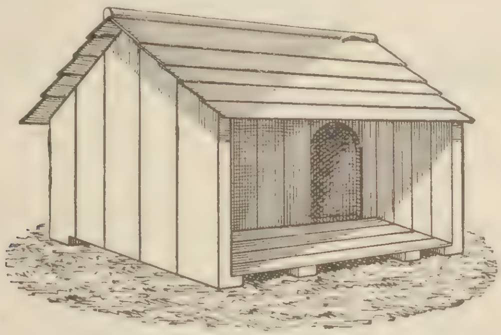

Fig. 251. Dog kennel with anteroom.

Finally, provision must be made so that the kennel can be cleaned easily and thoroughly. With the kennel shown in Fig. 250 this can easily be accomplished because of the sliding door. In addition to this, one wall is arranged so that it can be opened up for this purpose.

Fleas soon establish themselves in dog kennels. Concerning the extermination of these parasites, see page 318. A preventive against the flea plague is the use of a petroleum cask as a dog kennel, washed out with a hot soda solution and placed on low legs.

A wooden rack (Fig. 248) is generally placed in front of the kennel for the dog to lie upon. To give more opportunity for exercise, the dog should be chained at times to a long leash rod or be allowed to run about loose in a cage.

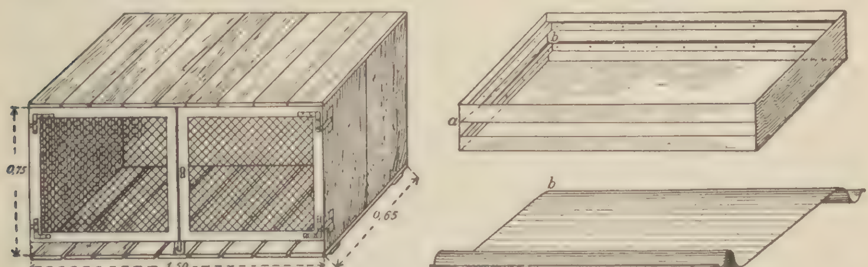

Fig. 252. Rabbit hutch. (After Boedecker.)

XIV. Rabbit Hutches

Hutches for rabbits are best constructed as shown in Fig. 252. They should be provided with floors that can be taken out in order to assure a more satisfactory cleaning.

XV. Poultry Houses

To assure a production of winter eggs the poultry house should be kept sufficiently warm during the winter (5 to 8°C, 41 to 46,4°F.). Chicken and turkey houses that stand in the open are often too cold in the winter. For this reason they are frequently built into the barns

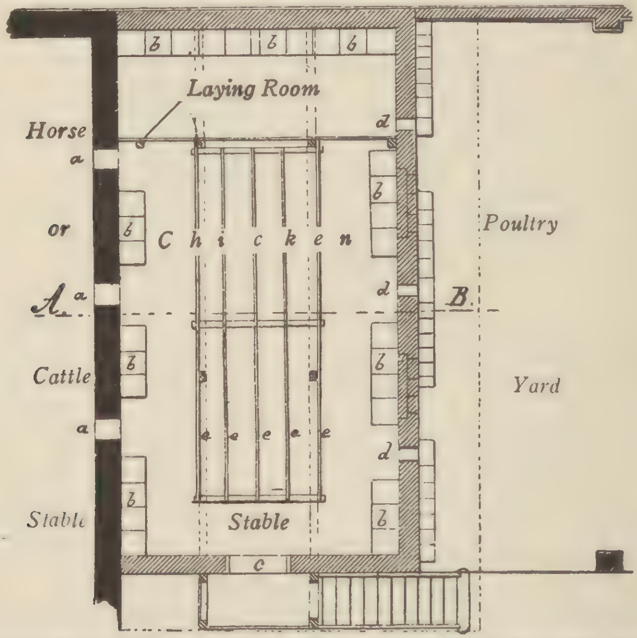

Fig. 253. Poultry house built on large animal stable. *a*, Opening with wire mesh toward stable; *b*, nests; *c*, door; *d*, holes; *e*, roosting poles.

over the stalls and pens. This is not to be recommended hygienically, since dirt and dust as well as bird mites, which often occur among poultry, fall down upon the animals that stand below, soil them, and above all may also seriously disturb their health (inflammation of the skin and of the external auditory canal, with severe excitement, etc.). It is preferable to build the poultry house against the cow barn (Fig. 253) and to perforate the partition-wall with holes (*a*) that can be closed with slides in case of necessity. The partitions should be constructed of firm material without cracks. Plastering supported with lath, hard gypsum tiles, smoothly finished paneling, brick walls, or smoothly planed, whitewashed boards that fit into one another, are suit-

able for this purpose. The warm stable air is allowed to penetrate into the poultry house through windows having gratings.

With far less provisions the poultry pen is sometimes built into the sheep barn.

Occasionally sheds, barns and carriage houses that are standing empty are utilized as poultry houses. Large spaces are divided by walls into roosting, scratching and laying pens about the height of a man, and these are provided with small connecting doors. With smaller spaces the roosting and laying hens are combined in one pen, which is separated from the scratching pen.

Sometimes use is made of the warmth of factories (boiler house, chimney wall, etc.), against which the poultry pens are built to secure warm rooms for special branches of poultry raising (winter breeding, fattening young chicks).

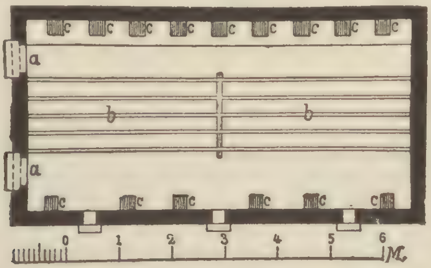

Fig. 254. Inner arrangement of a chicken house. *a*, Doors; *b*, roosts; *c*, nests.

If separate poultry houses are to be constructed, which is to be recommended, they should, if possible, have their main frontage toward the south or southeast, and care should be taken that the sunlight is not kept off the house by buildings or trees near by, since young birds especially prefer the sun and warmth. The walls should be built fairly thick so that the rooms will not become too cold, and should be whitewashed once or twice a year.

Wood is usually used as building material. Single board walls are cold in the winter and hot in the summer. Double walls are of course better, when possible upon solid foundation, with a layer between, 10 centimeters (4 inches) thick, of peat dust, tanbark, coke ashes, or some other poor heat conductor. The boards ought generally to be painted on both sides with carbolineum (creosote oil), should be grooved or provided with supporting strips, and if possible should be covered on the outside with tar paper and coated on the inside with thick whitewash to which some chlorid of lime, raw cresol, etc., should be added, to prevent if possible the entrance of vermin. An excellent building material for fowl pens is the fireproof, durable, hard gypsum tiles that can be sawed and nailed and which likewise are erected as double walls. Brick walls (1 to 1½ bricks in width) of hard baked bricks are good. Paneling, and air-dried clay bricks are good for poultry houses only

when they have been smoothed off on the inside and been whitewashed; otherwise their grooves and cracks harbor vermin.

Fig. 254 gives an idea of the inside arrangement. The floor should be raised 15 to 30 centimeters (6 to 12 inches) above the outside ground. Asphalt and concrete floors are recommended. For large poultry stock, which is chiefly to be considered here, the height of the house is 2 to 2.5 meters (6 feet 6 inches to 8 feet). The house is often given a slope toward the back to 1.60 and even to 1.25 meters (Fig. 255). The divisions should all, excepting the rather dark breeding rooms, be given ample light by means of high windows. Adjustable windows which tip, which at the same time serve for ventilation, are worth recommending. Furthermore, care should be exercised that beasts of prey (martens, cats, etc.) as well as stable vermin (rats, etc.) have no access to the poultry houses.

If poultry is being raised on a large scale, a roosting pen, a laying pen, a room for raising little chicks and, if possible, a place for broody hens are necessary.

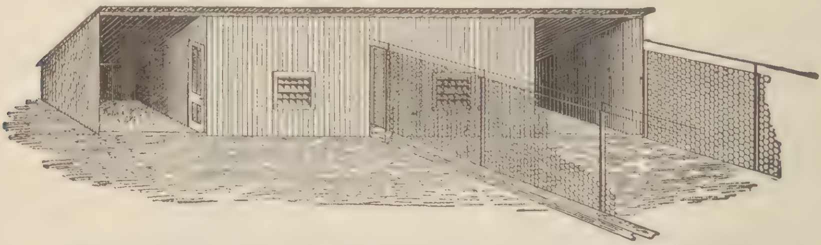

Fig. 255. Chicken house with open dusting pen on side and runway in front

The space required for the roosting pen is estimated as follows:

For 1 turkey	0.30—0.35	square meter[11] floor space
1 goose	0.25—0.50	" " " "
1 duck	0.15—0.35	" " " "
1 chicken	0.12—0.20	" " " "

Removable roosts, slightly cornered, 4 meters (13 feet) long, 5 centimeters (2 inches) thick, are put up about 40 centimeters (16 inches) apart. A roosting space of 20 centimeters (8 inches) is allowed per bird.

The separate divisions of the house should be of such a size as to accommodate 20 to 50 birds. Larger divisions are more difficult to oversee and in case of epizootics more difficult to separate. If several breeds are being raised a separation is necessary to avoid crossing and fighting. With light breeds one good cockerel is given 10 to 12 hens for proper fertilization of the eggs; with heavier breeds, 6 to 8 hens. Such breeding stock should have its own small pen and yard which is divided off by wire netting (Fig. 256).

[11] A square meter is slightly more than a square yard.

Sufficient ventilation should also be provided for the poultry house. Although windows can be used for this purpose during the warmer time of the year, they are more or less impracticable during colder weather; the house would get too cold. Arrangements for ventilation

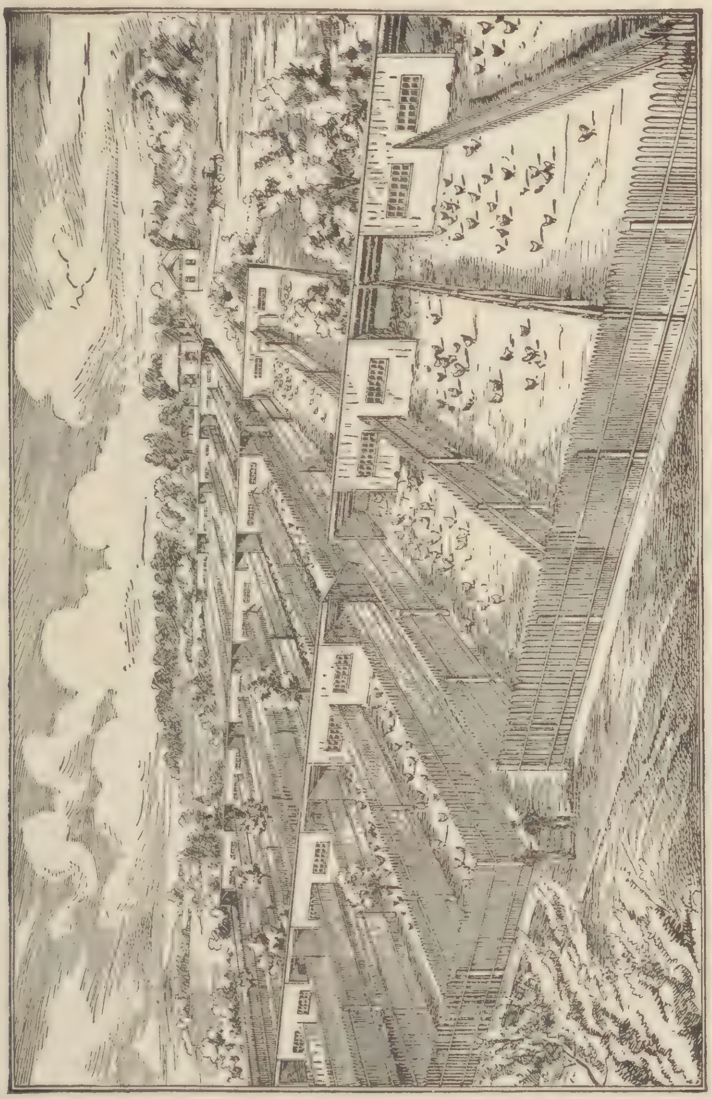

Fig. 256. Poultry farm.

similar to those used in stables are used (page 276). The ventilating flue illustrated in Fig. 257 has proved itself especially satisfactory for roosting, laying and fattening pens.

In pens for little chicks special care must be taken that the incoming

fresh air is first warmed. A heating plant must also be provided for cool and cold days.[12]

A layer of dry sand and ashes or peat dust is scattered on the floor of the roosting pen, and chopped straw or chaff is often used in the scratching and laying pens.

Entrance and exit are given the birds through a hole 20 to 25 centimeters (8 to 10 inches) across and 25 to 30 centimeters (10 to 12 inches) high at the bottom of the door or on the south wall, which can be closed by means of a slide.

To give birds that range opportunity to leave the pens early, an automatic arrangement for opening the holes is often constructed (Fig. 258). If the roosting place is high, boards with cross strips nailed 10 to 15

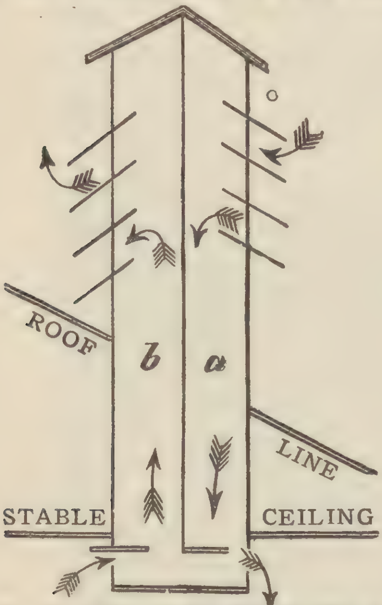

Fig. 257. Vapor or fume flue according to Waldson. *a*, Entrance of air; *b*, exit of air.

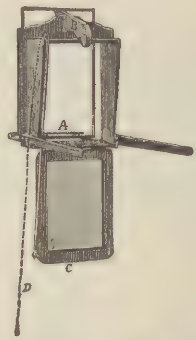

Fig. 258. Automatic stable opener. As a result of hen stepping on tread board *A* the lever *B* is pulled from trap window *C* which then falls down.

centimeters (4 to 6 inches) apart will serve as steps.

A poultry house also deserves proper care. It should be dry, clean, well ventilated, and free of vermin and disease germs. This is accomplished by cleaning it thoroughly several times a year. All wooden parts should be scraped off and scrubbed with a hot 2 per cent soda, tobacco or soap solution or a creolin solution and then whitewashed with milk of lime to which ½ liter of creolin has been added for each pail of whitewash.

The room used for hatching should be quiet, half dark, easily ventilated, but free of drafts. It should be on the level ground and often

[12]For further information regarding incubation, brooding, poultry-house construction, poultry pests, etc., see publications of the United States Department of Agriculture.—J. R. M.

supplied with a heating plant, since the young chicks are very sensitive to cold. To keep the birds free from dust, dirt and danger of fire, the room is heated by a stove placed in a vestibule or by means of central heating, etc.

The scratching pen should face with its open side toward the south or southeast and be next to the roosting pen (the main part of the house). It should be as large as possible, allowing about ½ square meter for one bird.

Reference has been made to litter. An ash or dust bath should be provided in a corner in a flat box about 25 centimeters (10 inches) deep. During the summer several spoonfuls of flowers of sulphur or fresh insect powder are added to the ashes or dust to destroy the vermin. A box with old building rubbish that contains lime (old mortar) and another with coarse sand or grit should be placed in the poultry house. The building material containing lime gives the birds the lime salts that

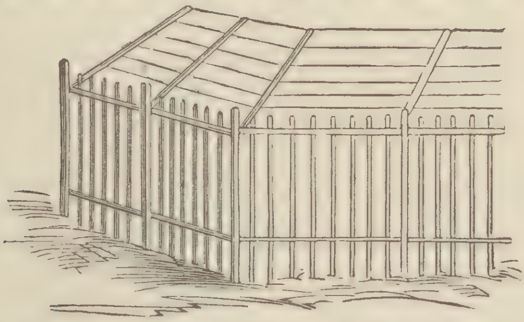

Fig. 259. Arrangement to prevent flying over fence.

are necessary for the formation of egg shell, etc., and that should also be supplied through the feeding. The coarse sand should be fed to assist the gizzard and to stimulate digestion. To encourage the birds to exercise grain is scattered in the litter; turnips, heads of cabbage, etc., are hung about 40 to 60 centimeters (16 to 20 inches) above the floor so that the birds can pick at them only by stretching the body or by jumping.

The scratching pen can serve as a shelter for the birds, especially during wet, cold weather or on windy days. When the weather is pleasant they should be turned into the runs.

The run should be sunny and dry. Ten to fifteen square meters (11 to 16½ square yards) are allowed per bird. On farms the yard, manure heap, orchards, meadows, etc., serve as runs. Bushes and trees for shade, small sandy places, and little compost heaps are welcome in the runs. On open range without trees or bushes the necessary shade is provided for the birds by means of shelters 1 to 1½ meters (yards) high and 2 to 3 meters long. The range should be sown with grass, clover, spinach, millet, serradellia, peas, oats and other plants that serve as green food.

The fence inclosing the run must prevent the birds from crawling through or flying over. A fence of lath or wire netting 2 or 3 meters in height is used. The laths should be fastened 1.5 to 2 centimeters (⅝ to ¾ inch) apart at least to a height of 60 centimeters (2 feet) above that height they may be 7 centimeters (2¾ inches) apart. Oak posts or light stone pillars are used as supports for the laths. The wire netting is more durable, allows light and air to penetrate more easily, and usually is cheaper than a lath fence. The best mesh for the wire netting is 20 to 25 millimeters (¾ to 1 inch).

To prevent the birds from flying over it is advisable to lengthen the fence upward and inward as shown in Fig. 259.

Sometimes the birds are brought to the stubble fields, freshly ploughed fields, pastures, clover fields, etc., in portable poultry houses (abandoned coaches, reconstructed carts, etc., with roosts and nests). Here they devour quantities of destructive insects and weeds and usually manage to get along without extra feeding.

The nests for laying and broody hens are built in boxes 26 to 42 centimeters (10 to 12 inches) in width with partitions high enough so that the hens can neither see one another nor touch one another with their tails.

For fattening purposes the birds are frequently put in cages or crates which are 41 to 46 centimeters (16 to 18 inches) long, 24 to 26 centimeters (9½ to 10¼ inches) wide and 25 centimeters (10 inches) in height for capons and hens. A crack is left in front so that the bird can put its head through to reach the feed and water, which are placed outside the cage. At the bottom of the back part of the cage wire netting is arranged so that the excrement falls upon the floor of the fattening room, from where it is easily removed.

Every poultry place should have a space reserved for sick birds, a quarantine pen in which newly bought birds or birds returning from exhibitions should be placed and watched for at least eight days.

Particular care should be taken during the molting season. Especially poorly nourished, weak chickens and those that have lost most of their feathers should be protected against catching cold and should be well nourished by receiving nitrogenous feeds, feeds that contain silicic acid and lime and that form feather. To prevent the birds from developing the habit of eating their eggs, only dry, finely crushed eggshells should be given them, and only porcelain or gypsum eggs should be used as nest eggs. The addition of meat meal and ground bone usually acts satisfactorily in stopping the habit of eating feathers. Keeping the birds free from vermin is also important with regard to this habit. Since bad examples may easily spoil good habits, it is advisable to kill promptly the birds that eat feathers, unless they are very valuable birds.

Since poultry is also susceptible to most poisonous plants and other harmful forms of food, the measures of precaution mentioned in pre-

ceding chapters should be observed. Poultry feeding is discussed in another section of this work.

Pens for ducks and geese should be built level with the ground near water, which is a necessity of life for ducks.[1] Geese are given a grass run. They destroy too much in gardens, young fields and meadows. Ducks and geese should be kept properly separated. Their pens, as well as those for poultry, should be protected against animals of prey, should be light, clean, well ventilated and dry. Even ducks are sensitive to the wet, even though they spend a great deal of time on the water.

Fig. 260. Chicken wagon.

A half-dark laying and hatching room should be connected with the main part of the pen. Otherwise what has been said concerning poultry can be applied to pens for ducks and geese.

Nests for brood *pigeons* are arranged in rows above one another and should measure 46 by 60 by 46 centimeters (18 by 24 by 18 inches) in size and be provided in front with a trap door 15 centimeters (6 inches) square. A roost should be placed 20 to 24 centimeters (8 to 9½ inches) in front of every row of nests.

[1] Many ducks have been successfully raised and brought to market which never had access to water except that which was in drinking vessels.—Translator.

Section VIII

Contagious Diseases

A. The Nature and Causes of Contagious Diseases

By *contagious diseases* are understood such parasitic diseases as possess a decided tendency toward spreading and are difficult or even impossible to cure and through fatalities or a decrease in production cause great pecuniary losses. In other words such diseases are of greater economic importance in comparison with other parasitic diseases.

Contagious diseases are classified according to the area they cover when spreading.

1. *Local contagious diseases* (*enzoötics*). These diseases, which correspond to endemics[1] among humans, are more or less localized, i.e., restricted to a certain locality. The soil (soil diseases) or the water plays an important part in their transmission, thus determining the localization. To these belong anthrax, blackleg, swine erysipelas, infectious abortion, contagious spinal meningitis of horses, etc.

2. *Generalized contagious diseases* (*epizoötics*). These diseases correspond to epidemics[1] among humans. To distinguish them from the diseases named under No. 1, they show a decided tendency to spread over greater areas within a shorter space of time. Among these are foot-and-mouth disease, sheeppox, rabies, rinderpest.

3. *Panzoötics*. By this we mean virulent forms of diseases that occur over a wide area and attack more than one kind of animal. Anthrax appeared frequently in the form of a panzoötic during ancient times, during the middle ages, in more modern and very recent times (1864-66 in Russia and even during the last ten years in Siberia). Tuberculosis rages at the present time as a panzoötic in most civilized countries.

The *causes* of most contagious diseases have been proved to be definite, specific *living organisms* (parasites). Even with regard to contagious diseases whose causes are not yet definitely known (for example, rabies, foot-and-mouth disease, smallpox, rinderpest, fowl pest, hog cholera), the cause is definitely accepted to be an agent that can multiply, namely, living organisms. These living organisms (parasites) which cause diseases and special contagious diseases belong to:

1. The vegetable kingdom, for which reason they are designated as *plant parasites*. The most important representatives are the *bacteria*

[1]Derived from δῆμος = the people.

(fission fungi, Schizomycetes). The other chief group, the higher fungi or Eumycetes, to which the molds, fodder fungi, the causes of skin eruptions, yeast fungus, etc., belong, are of minor significance as causes of diseases of animals. Diseases caused by plant parasites are spoken of as *infectious diseases.*

2. The animal kingdom. These *animal parasites* belong partly to the primitive animals (Protozoa), partly to the worms (Vermes), partly to the jointed animals (Arthropoda). The diseases caused by them are called *"invasion diseases."* Occasionally certain diseases caused by protozoa are also called infectious diseases, which, however is not correct.

Microörganisms are divided, according to their relation to the living plants, animals and humans, into parasites and saprophytes. Those microörganisms which live on or in dead bodies are called *saprophytes* (putrefactive bacteria). Those organisms that thrive in or upon living organisms, and draw their nourishment from these organisms (which are called the hosts), are known as *parasites.* Transitions exist between both. There are parasites that as the occasion demands can lead a saprophytic existence (facultative saprophytes) for a longer or shorter period of time, and on the other hand there are certain saprophytes, the so-called facultative parasites, which under certain conditions penetrate into the animal body and cause diseases. Certain other saprophytes, e.g., lactic-acid bacilli and *Bacillus prodigiosus,* lose the ability to be parasitic and are therefore called obligate saprophytes. In like manner there are certain parasites that can only lead a true parsitic existence, e.g., the tuberculosis and glanders bacilli; these are known as obligate parasites.

The characteristic difference between pathogenic and putrefactive bacteria consists in their *infectiousness,* i.e., their ability to multiply in living tissue. Parasites are infectious. Saprophytes, on the other hand, can not penetrate into the living tissue and multiply there.

With regard to their characteristics no definite line can be drawn between parasites and saprophytes, for here, as so often in nature, transitions occur. Such a link between pathogenic bacteria (e. g., the blackleg bacillus) and putrefactive bacteria (e. g., *Bacillus botulinus*) exists, for example, in the diphtheria and tetanus bacilli. All four kinds of bacteria possess in common the property of being able to form toxin with which they can poison susceptible animals; but they can be distinguished by their infectiousness. *Bacillus botulinus* is a true saprophyte. The diphtheria and tetanus bacilli grow in the animal and human body and form toxin there, but they can only multiply on the upper surface of the mucous membranes or in tissue which has previously been killed by mechanical or chemical injuries; they can not penetrate into healthy living tissue. On the other hand the blackleg bacillus is decidedly infectious. That no absolutely insurmountable barrier exists between the parasites and saprophytes is also shown by the attempts to breed infectiousness into saprophytes (e. g., *Bacillus megatherium, B, mesentericus, B. subtilis, B. prodigiosus*), and the reverse, to rob the pathogenic bacteria of their infectiousness.

Furthermore, the disease bacteria are not infectious for all kinds of animals but only for those that are susceptible. They act as saprophytes toward animals that are not susceptible. But they can eventually be made infectious for

these animals, as Dieudonné has shown with the anthrax bacillus in relation to pigeons and frogs.

Infectiousness (i.e., the ability to grow in the living organisms) is an essential part of *virulence,* by means of which it is often identified. By the virulence of pathogenic bacteria we mean the sum total of their specific actions in creating diseases, to which the *toxicity* (degree of being poisonous) is also often added.

Infectiousness and toxicity do not, as has already been shown, go hand in hand. With the tetanus bacillus as a cause of disease the toxicity plays the important part; with the anthrax bacillus the infectiousness is most important. Among the blackleg bacilli there are certain strains that are distinguished by high toxicity and low infectiousness, others by high infectiousness and only low toxicity.

The nature of the virulence (infectiousness) has not been discovered. Morphological differences between virulent and avirulent bacteria are not known. The Babes-Ernstchen polar bodies are of no use in this direction. Wassermann has proved quantitative differences in the receptors among typhoid bacilli.

The degree of virulence is often only relative. An increase in virulence can occur for one kind of animal with a decrease of virulence for another kind of animal. Erysipelas bacilli that are virulent for swine are generally only slightly or not at all pathogenic for rabbits. If, however, they are adapted to rabbits by passage through rabbits, they become virulent for them and at the same time lose their virulence for hogs.

The virulence of bacteria can be affected artificially; it can be lowered as well as raised. This fact is of great practical interest. Weakened and even a virulent bacteria are frequently used in immunizing against infectious diseases, while infectious substances that have been artificially increased in their virulence are used to destroy vermin (rats, mice).

A *lowering of virulence* (*attenuation*) occurs spontaneously during artificial propagation on a nutrient mediun. With artificial cultivation the decrease in infectiousness is accompanied by a slow or rapid adaptation (depending on the kind of bacteria) to a saprophytic mode of life. The microörganisms of old cultures are injured somewhat by drying and by the oxygen of the air. The virulence sometimes returns in fresh young cultures, while in the case of other kinds of bacteria they remain weakened. The decrease in the virulence of old cultures was the first obsrvation made regarding the change in the virulence of pure cultures. Pasteur established it in the year 1880 by his tests with fowl cholera. This gave him the motive for further study in this matter, of which the most valuable result was the discovery of various methods of protective inoculation, as against anthrax, erysipelas and rabies.

The following procedures are chiefly used to decrease the virulence artificially:

1. The influence of a higher degree of temperature. The cultivation is done either with a slightly raised temperature (42-43° c.), or the microörganisms that were grown at the most favorable temperature are exposed for a longer or shorter period of time to higher temperatures.

The first method is applied in weakening the anthrax bacilli for the purpose of protective inoculation according to Pasteur. A temperature of about 52° c. is used for several hours for attenuating vegetative growths, and a temperature of 85-105° c. for materials containing spores (blackleg protective vaccine according to Arloing, Cornevin and Thomas).

2. Passage through certain kinds of animals. This principle was applied in smallpox vaccination, discovered empirically by Jenner and first used in an ingenious manner by Pasteur in swine erysipelas. He innoculated rabbits with the erysipelas bacteria. The erysipelas bacteria that were thus weakened sufficiently for swine were then used as vaccine for hogs. The rabies virus loses its virulence for people by passage through rabbits. Human tubercle bacilli become avirulent for humans and mammals by passage through certain cold-blooded animals.

3. Drying and other physical actions (sunlight, electricity, etc.). Pasteur made use of the decrease in virulence obtained by the drying process in producing his vaccine against rabies.

4. Chemical means. The virulence can be diminished without killing the bacteria if they are subjected for a short time to the action of a weak concentration of chemical disinfectants (e.g., carbolic acid 1:180-600, potassium dichromate 1:2,000-5,000. Chamberland and Roux, sulphuric acid 1:200, chlorin water 0.1-0.2 per cent. Geppert, iodin tricholorid, Lugol's solution, carbon disulphid, oxygen, ozone, hydrogen peroxide, etc.). Certain substances of animal cells (leucocytes) act similarly.

An *increase in virulence* is accomplished at times by frequent transplanting of the particular infectious substances upon a suitable nutrient medium and especially by passage through animals. If possible the same kind of animals should be used for which the virulence is to be increased. Occasionally passage through birds should increase the virulence generally, as with mouse typhus bacilli for mice; on the other hand erysipelas bacilli gain on increase in virulence for hogs by passage through pigeons (Voges and Schuetz), as was the belief for a long time based upon data of Pasteur.

Diseases caused by parasites are *specific diseases,* which, nevertheless, can at times appear, according to the organs affected, under different clinical symptoms. Reversing this thought, every infectious disease is caused by a very definitely characterized microörganism. Thus the *Bacillus tuberculosis* causes only tuberculosis, and tuberculosis is caused only by *B. tuberculosis.* However, the symptoms of tuberculosis may vary. The disease (diagnosis) is recognized by the detection of the bacteria, and important lasting points are gained for therapeutics, prognosis and prophylaxis. Since in the end everything depends on the specific cause of the infectious disease, the science of infectious diseases has become a decided etiological investigation.

In order to claim definitely a microörganism as the causative agent of a disease it is necessary—

1. To establish proof that the particular microörganism always appears with that particular disease and in such numbers, in such an arrangement and with such virulence that the appearance of the disease is explained hereby.

2. To make true and continuous growths of the microörganisms,

3. That the microörganism, transmitted from the pure culture to the susceptible animals, produce in them the particular disease.

B. Infection, Susceptibility and Resistance of the Animal Organism

The pathogenic organisms are not the sole cause of infectious diseases, for an internal cause of the disease (susceptibility, disposition) must be added to this causa externa to produce an infection. If the causa interna is lacking, the animals will remain well in spite of infection; the animals are then designated as not susceptible, or as immune, or as being refractory for that infectious disease. The disease bacteria must therefore enter into the susceptible animal to produce an infection.

The bacteria make various demands with regard to gaining entrance. It is taken for granted that the glanders bacillus and *Staphylococcus pyogenes* can even penetrate through the many layers of the horny squamous epithelium of the outer skin. The tubercle and anthrax bacilli can not do this, but can infect from true mucous membranes. Even this the tetanus bacteria and the malignant edema bacilli can not do, since they need slight wounds to gain entrance.

Susceptibility and resistance (immunity) are often not absolutely fixed contrasts, but are frequently and gradually changed by numerous physiological and pathological conditions of the organism and merged into each other. Both can be (*a*) natural and (*b*) acquired.

(*a*) *Natural capability of resistance* (*immunity*) may be peculiar—

1. To a certain species of animal. Thus horses are immune against contagious pleuropneumonia, cattle against glanders, sheep against erysipelas, hogs against distemper, etc.

2. To a particular breed. Algerian sheep are considered very capable of resisting anthrax (Chauveau). Hogs of the native [German] breeds and of the Berkshire breed are more resistant against erysipelas than the remaining English (e. g., Suffolk) breeds and the Poland-China hog.

3. To an individual. When epizoötics rage it is often noticeable that certain individuals do not take sick but resist the disease, in spite of the fact that all the animals of a farm were exposed to the disease (e. g., foot-and-mouth disease).

At the present time very little is known concerning the nature of natural immunity. The immunity of species can probably among other things be traced back to the fact that the particular bacteria found no susceptibility in that immune animal of that species and thus became inactive. Deviating temperature conditions must also be considered to a certain extent. Cold-blooded animals are usually immune from the infectious diseases of warm-blooded animals, and vice versa. Similar conditions exist between birds and mammals. Differences in the alkalinity of the blood can also affect the susceptibility.

Upon this Bering reduced the resistance of rats against anthrax. According to Fodor and Riegler, the blood of animals possessing the higher alkalinity possesses a greater bactericidal action.

With regard to breed immunity we are no doubt often dealing with acquired and hereditary immunity (resistance of Algerian sheep against anthrax, of native cattle against blackleg in districts where blackleg is raging, etc.).

With natural individual immunity it may be more a matter of a better development of the natural ramparts of the body (horny layer of the epidermis, efficiency of the ciliated epithelial cells, etc.), which can no doubt also play an important part in the immunity of species and breeds. In addition to these outer means of protection the animal organism also has at its disposal internal arrangements which determine its immunity. These appear to a great extent with immunity acquired by the action of specific agents and are to be mentioned under that heading.

(*b*) *The acquired capability of resistance*[2] (*immunity*) can be traced back to the action of ([1]) nonspecific or ([2]) specific agents.

1. As long as they do not directly affect the disease bacteria, the nonspecific agents have only a limited influence on the increase of resistance with animals kept under normal conditions. However, as much use as possible will be made of the nonspecific agents, and especially when specific agents are not known or are not applicable for outside reasons.

The nonspecific agents include:

(*a*) Influence upon the nutritive conditions. An undernourished condition produces a tendency toward disease (spreading of epidemics during famines); well-nourished conditions a certain resistance. Pigeons nourished normally are immune from anthrax; if weakened through hunger they are susceptible to anthrax. A lack of water lowers the resistance even more, as has been shown by the tests of anthrax infection by Pernice and Alessi with dogs and chickens.

The practical application to be deducted from these facts is self-evident.

(*b*) Overexertion. This injures the natural resistance in every form (forced milk production, bearing young, draft work, etc.) Psychic depression plays a part that should not be underestimated, at least among humans. These known facts can easily be demonstrated experimentally with rats. Rats kept under normal conditions are immune from anthrax; if kept in a revolving cage they become susceptible (Charrin and Roger).

In practice it follows that the animals that have been exposed to infection should be protected as much as possible against overexertion, and sick animals (especially those suffering from acute infectious diseases) should be given as much rest of the muscular and nervous system as possible.

(*c*) Colds and influence upon the activity and secretion of the skin. Colds lower the body heat, the skin activity, and presumably also the other secretions, as well as the resistance. According to Kisskalt, the

[2]Resistance is for practical reasons not separated from immunity. The essential difference between resistance and immunity consists in the fact that the development and action of immunity is specific, whereas those of resistance are not specific.

arterial hyperemia of the mucous membrane, etc., produced by irritation from cold lowers the blood alkalinity. According to Loewit, a temporary cooling off produces leucopenia (an impoverished condition of the blood with regard to leucocytes, those powers of defense of the organism against the microörganisms).

As to the prevention of colds, see page 31. To get rid of a cold that has made its appearance, the skin activity should be stimulated (rubbing, covering, sweating), also the remaining secretions (the excretion of eventual bacterial poisons, not so much the bacteria themselves).

(*d*) Therapeutic measures, (e.g., increasing the alkalinity of the blood and body fluids by administering bicarbonate of soda, etc.). The favorable influence of venous congestion is likewise partly attributed to an increase in the blood alkalinity.

Furthermore, mention should be made here of the injury done by disease producing bacteria that have penetrated by means of higher temperatures (hot compresses), by means of rays that act chemically (sunlight, Roentgen rays, radium emanation, etc.) in treating a superficial disease site; by chemical means (salvarsan against syphilis, pectoral influenza, etc.; salicylic acid for articular rheumatism, etc.) The disinfection of the body cavities that offer access from without (digestive canal, etc.) deserve more attention. Results have been accomplished against anthrax with creolin, against calf scour with ventrase, etc.

Mention must also be made of agents that provoke hyperleucocytosis (an increase in the number of leucocytes in the blood) and protoplasmic activation. To these belong tissue extracts, nuclein, spermin, albumoses and similar bodies, heterologous bacterial extracts, milk vegetable proteins; in short, heterageneous protein; also the sodium salt of cinnamon acid (hetol), etc. This temporary, gradual and very limited action of these agents appears only after parenteral (subcutaneous and intravenous) incorporation, but not when they are given in the digestive canal.

Finally attention should be drawn to certain surgical interventions, e. g., draining collections of fluid containing bacteria (pus from abscess, etc.) from the body, lessening the resorption of bacteria and their poisons by means of incisions into swollen tissues, direct annihilation of the bacteria by means of disinfectants, etc.

2. The specific agents that increase resistance produce immunity. Concerning this see the following section.

C. Immunity

I. General Considerations

As early as the year 1874 Traube and Gscheidel reported on the properties of blood plasma that destroy bacteria. In 1884 Groszmann

observed the unfavorable influence of the extravascular blood upon bacteria. The first exact tests along this line were carried out by Fodor in the year 1885. He observed that large quantities of pathogenic and saprophytic bacteria that were injected into the blood disappeared in a few hours without having been excreted by the kidneys. Later Fodor discovered that anthrax bacilli also died in the cardiac blood of a freshly killed animal. The positive proof of the existence of such bactericidal substances in the blood as well as in pleural exudates, liquor pericardii, etc., of rabbits, mice, sheep, dogs, pigeons, and people was furnished by Nuttal. He also observed that the anthrax and hay bacillus as well as *Bacillus megatherium* and *Staphylococcus pyogenes aureus* are destroyed in the designated body fluids, and that the bactericidal action of the blood is destroyed by prolonged heating at 55°C. As has been shown by the experiments of Nissen, this bactericidal action of the blood is limited quantitatively. Buchner furnished further important explanations of these bactericidal substances, which he later designated as alexins (Greek?) to prevent). He also identified them in serum that was free of cells. After numerous tests proof was established that the killing of the bacteria by the blood or serum was not dependent on the plasmolytic influence of the mineral salts of the designated fluids.

The specificity of the action of the blood serum of various animals toward various kinds of bacteria was shown by the tests of Behring and Nissen. Evidence was established by the tests of Hankin, Denys, Buchner, Hahn, Bail and others that the leucocytes are capable of producing bactericidal substances. Furthermore the investigations of Ehrlich and his pupils showed that the bactericidal action is far more complicated than the tests of Buchner formerly led us to believe. Proof was finally established that the bactericidal substances are also present in the circulating blood and do not only appear in blood that has been drawn, as a result of the destruction of the leucocytes, as Metchnikoff and his coworkers, also Gengou and Bordet and others supposed.

Acquired immunity is strictly specific with regard to its origin as well as to its action. The substances that give occasion to the origin of immunity are designated as *antigens*. Their immunizing effect depends on the development of specific *antibodies*. This process is spoken of as active immunization. Since the antibodies pass into the body fluids (blood, etc.) of the actively immunized animal, they can be transmitted with this fluid to another animal (passive immunization). The blood serum is used for such a transmission (serum therapy). Active immunity tends to last quite a while (half a year and more), the passive only about two or three weeks. The formation and action of antibodies is decidedly specific.

If, for example, red corpuscles of sheep are used as antigen to immunize rabbits, they develop an antibody whose action extends only to the antigen used for immunizing. They therefore act only upon red corpuscles of the sheep, but not upon those of the horse, hog, dog, etc. But even with the sheep they act only upon the red corpuscles and not upon liver cells, spermatozoa, etc. Just

as the action of this antibody is strictly specific, its development is also definitely specific. This antibody with this action will be developed only under the influence of this particular antigen, and not from one that has its origin in some other kind of animal or cell.

The development of antibodies extends only to protein substances and toxins. No antisubstances (antidotes) can be formed against poisons that are not toxins, e. g., alkaloids (morphin, nicotin, etc.), inorganic poisons (arsenic), alcohol, nor against fats, carbohydrates, etc. A capability of resisting ordinary poisons depends rather upon an accustoming (or acquired tolerance) of the tissue, which is also referred to as histogenic immunity, to distinguish it from the humoral, with which the antibodies pass into the body fluids (blood, etc.). Histogenic immunity is not only of importance with ordinary poisons, but above all with certain infectious diseases (tuberculosis).

The following antibodies will be mentioned here:

Antitoxins, which bind the toxins and thus make them harmless.

Precipitins, which precipitate protein substances in solution.

Agglutinins, which agglutinate free cellular structures.

Complex lysins, which consist of immune bodies (amboceptor) and of the complement already existing in the blood of animals not previously treated, and which dissolve or kill (bactericidal substances, cytotoxins, etc.) cellular structures (bacteria: bacteriolysins; red blood corpuscles: hemolysins; other animal cells; cytolysins).

Bacteriotropins and opsonins, which render bacteria susceptible to the action (ingestion) of phagocytes, and antiaggressins, which take up the aggressins of bacteria and again make possible the access of the phagocytes that had been driven off by the aggressins.

The remaining antibodies may be omitted from this discussion.

The importance of antibodies to the organism lies in the fact that the organism can guard itself with these antibodies against dangers that have penetrated it (e. g., bacteria and their poisons). This, however, does not end their practical importance. With their strictly specific origin and action the precipitins, agglutinins, immune bodies, etc., are of great use in clinical and bacteriological diagnosis, in determining the origin of flesh, blood, etc. Within the limited space of this book I can not further discuss serodiagnosis nor protective and curative vaccination. I have therefore treated these practical, exceedingly important subjects with the cooperation of other authors in special books, serodiagnosis in the "Manual of Food Analysis," edited by Bythien, Hartwich and Klimmer, published by Chr. Herm. Tauchnitz, Leipsig, and the methods of inoculation in the "Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine," edited by Klimmer and Wolff-Eisner, published by Dr. W. Klinkhardt, Leipsig.

When a causative agent of infection enters an animal organism, a mighty struggle ensues between the two, which usually ends in the complete annihilation of the one or the other combatant. Both parties

have weapons of attack and means of protection at their disposal. Those of the bacteria are the poisons (toxins) and the capability of resistance (resistance or infectiousness). Those of the animal organism are the agents that destroy bacteria (bactericides) and the substances which make the bacterial poisons harmless, the antidotes (antitoxins).

II. Toxin and Antitoxin

Great importance is attributed to the *poisons of bacteria* in the appearance of symptoms of a disease and the fatal course of an infectious disease. With many, perhaps with all, infectious diseases it is not the bacteria alone but their poisons that at the last cause the degenerative changes and death. This assumption is especially convincing with infectious diseases whose causative agents are limited to the site of infection and yet cause the severest, even fatal diseases, as is the case, for example, with tetanus, diphtheria and Asiatic cholera.

The poisonous substances are partly liberated by the bacteria, partly locked in their body protoplasm. Sometimes they only produce cleavage products and products of decomposition of the nutriments. The poisons locked in the bacterial cell are not set free until after the bacterial cell has been destroyed, while on the other hand the first and last groups of poisons pass over into the nutrient medium and can be separated from the living cultures at hand by means of filtration through vessels (bacterial filters) of baked porcelain clay (kaolin, Chamberland filter L), baked diatomaceous earth (kieselguhr, infusorial earth, Berkefeld filter), etc., or by careful extermination of the bacteria by means of heating to 55-60° C., or by the action of chloroform, ether, etc., and can easily be identified in an experiment on an animal.

The majority of poisonous substances can easily be classified in the following three groups:

1. *Nonspecific poisonous substances,* which in suitable numbers cause animals to fall sick and even to die, but which under natural conditions, namely, in the infected animal organism, never arise in such numbers that they need be considered causatively with regard to the disease symptoms and the details of the infection. Among these we must consider nitrite, various sebacic acids, phenols, aromatic acids and other aromatic substances, as particularly ptomains. These substances are of interest only because they have a disturbing effect in the determination of specific bacterial poisons, especially in old bacterial cultures and when large quantities are used; they can easily cause mistakes to be made.

Of the poisonous substances mentioned the *ptomains* especially demand attention. They were first observed by Nencki, Selmi and Panum, and were studied more closely by Brieger. The ptomains, which are formed by the extensive decomposition (decay) of protein matter, as especially meat, are alkaloidal, basic substances (amins), of which only a small number (neurin, muscarin, ethylendiamin, mydatoxin, methylguanidin, mytiltoxin) are distinguished by poisonous properties. Among other things Brieger has isolated the following ptomains (the poisonous ones are italicized):

1. From decaying fish meat: Cadaverin, putrescin, methylamin, dimethylamin, trimethylamin, diethylamin, *ethylendiamin,* neuridin, *muscarin,* gudinin.
2. From decaying beef; *Neurin,* neuridin, *mydatoxin, methylguanidin.*
3. From decomposing parts of a human cadaver: Cholin, neuridin, cadaverin, putrescin, saprin, trimethylin, mydalein, mydin.
4. From decaying edible mussels: *Mytiltoxin,* betain, cadaverin, putrescin, trimethylamin.

When ptomains were also found in the fluid cultures of pathogenic bacteria (typhoid bacilli, tetanus bacteria) the ptomains verged upon being made accountable for the poisonous action of the bacteria. But it was soon discovered that some of these ptomains, as has been mentioned previously, were not at all

poisonous, that others were poisonous but did not produce the typical infectious disease, while others appeared only as artificial cleavage products through chemical intervention during the isolation. Today we know that the ptomains, and with them the other members of this group, are not considered as—emphasizing it again—noxious substances under natural conditions, namely, in infected animal bodies. These poisonous substances also play no important part in meat poisoning, for they do not develop until the decomposition is far advanced and has reached the putrid stage, and even then only in small quantities.

Later Brieger thought he had found the bacterial poisons in the *toxalbumins*, but he had to give up this supposition, especially after proof was established that the toxalbumins were a mixture of albumoses and toxins which were precipitated together, the latter by the former during their precipitation (Wassermann and Proskauer).

2. Another group of the poisonous substances are those which are bound to the bacterial protoplasm and which are called intracellular toxins. To these belong the proteins of the bacterial cell, the so-called *bacterial proteins* (Buchner).

The physiological action of the bacterial proteins is not specific in its "pure toxin-free" condition, but corresponds with those albuminous substances foreign to the body, i. e., they produce an inflammation, aseptic suppuration and necrosis wherever they are injected into the living animal body; at the same time they also cause trifling generalized symptoms such as fever, weakness, headaches, etc., and allow the development of partly bactericidal, immunizing processes and specific precpitins, which are produced for the sake of protection.

But there are also certain bacteria whose protoplasm is decidedly toxic. This toxicity may depend on the fact that the particular bacterial protein is itself poisonous or that specific poisons are mixed with the body substance, which are called, according to Pfeiffer, *endotoxins*, to distinguish them from the excreted (soluble) toxins. The name exdotoxin is not well chosen, in that these intracellular poisons in no way correspond in their physiological action (formation of antitoxin) to the well-characterized group of toxins. They have only the high poisonous quality, and their unstability in common with toxins. A haptophore and toxophore group peculiar to the toxin molecule has as yet not been demonstrated with the endotoxins. The endotoxins cause fever or a sudden drop in temperature; at the same time a severe decrease in metabolism occurs (rapid loss in weight, even marasmus that may prove fatal); locally suppuration and necrosis. Endotoxins are of importance with typhoid, cholera and dysentery bacilli, etc.

Endotoxins can be obtained by the filtration of old bacterial cultures. The bacteria are dissolved by autolysis and the endotoxins are liberated. The endotoxins can also be extracted with a physiological sodium chlorid solution from bacteria killed at 60°C. Or the bacteria may be dried and extracted in a mortar with small quantities of a concentrated salt solution.

Finally even simpler substances were demonstrated by Ruppel in the tubercle bacilli. These are called tuberculosamin and the tuberculin acid. They are said to exercise a specific effect. Their significance is still doubtful.

3. *Toxins.*—New viewpoints and proofs of the significance of the bacterial poisons for certain infections diseases were established with the discovery of the toxins. As yet poisons have not been demonstrated with all pathogenic bacteria. The supposition is generally accepted that many bacteria form no poisons, at least no toxins.

In order to secure toxins the bacteria are grown in suitable liquid nutrient mediums (bouillon) under favorable conditions. Where sufficient toxin has been formed, the cultures are filtered through a bacterial filter, and thus the toxins, dissolved in the nutrient medium, are separated from the bacteria. Toxins have as yet not been produced in a pure state.

The chemical constitution of toxins is unknown. It shows many conformities with the enzymes. It is free of nitrogen, therefore has no protein. The toxins are very labile compounds that lose their poison through insignificant intervention, as, for instance, through weak mineral acids (the acid gastric juice) excepting the toxins of *Bacillus botulinus* and *B. paratyphosus* B, the chief causes of meat poisoning; also through lyes, sunlight, oxygen and all agents of oxidation; alcohol, iodin, thyroid solutions, as well as by heating above 60°C. in a damp condition, excepting the *B. paratyphosus* B toxin, which withstands boiling. On the other hand low temperatures do not destroy the action of the poison, but weaken it as long as the low temperatures exist.

The digestive enzymes (pepsin, trysin, bile) are harmful to most toxins. Therefore the latter are generally inactive in the digestive tract, excepting the botulism and paratyphus B toxins, as well as ricin, a vegetable toxin that occurs in the castor bean.

The toxins are distinguished by an extremely poisonous action toward susceptible animals. Thus the tetanus toxin (tetanus poison) is about 25,000 times more poisonous than the highly poisonous alkaloid strychnin. Although the differences in the action of ordinary poisons upon all animals are very insignificant and such poisons kill quickly, the toxins act only upon certain animals that are susceptible to the toxin, and then only upon certain cell complexes, whereas they are often ineffective toward animals that are often closely related but not susceptible.

The action of tetanus and botulinus toxins extends to the central nervous system, they are neurotoxins; those of the staphylot lysins, tetanolysins and pyocyaneolysins upon the red blood corpuscles (hemotoxins); of the staphyloleucotoxins, upon the white blood corpuscles and kidney epithelium (leucotoxins and nephrotoxins). Furthermore, the poisoning usually takes place after a longer period of latency or incubation. Thus tetanotoxin, even in the deadly 100,000-fold doses, does not kill until after 12 hours.

Only with snake poisons that otherwise correspond exactly with the

bacterial toxins and with the vibriolysin is the period of incubation lacking or very short.

The mere presence of toxins in the blood is not alone sufficient for their toxic action; rather, in order for their action to evolve itself, they must combine with the cells that are susceptible to the poison, upon which their toxicity then takes effect. No poisonous action results without union, as the following tests will prove.

If tetanus toxin is injected into a turtle, the animal does not become sick, and the poison can be demonstrated in the blood for weeks, undiminished and fully active. If, however, the tetanus toxin is injected into a guinea-pig, the toxin disappears entirely from the blood within a few minutes after the injection, and after the period of incubation has terminated the guinea-pig is taken sick with tetanus.

In the same manner that two chemical substances unite only when an affinity exists between them, so the toxin combines with the body cell only if the cell possesses an avidity for the poison. That part of the toxin molecule that effects the union with the body cell is designated in the nomenclature of *Ehrlich's side-chain theory* as *haptophore* (ἅπτειν — to seize, φέρειν — to carry) *group,* and that part of the body cell (the nucleus of service — Leistungskern — of the functioning protoplasm—Ehrlich) with which the union takes place as *receptor* (side-chain[3]). The toxin molecule has in addition to the haptophore group another group which is the carrier of the poisonous action; it is accordingly called the *toxophore* group (Fig. 261).

The mere union of the toxin molecule with a body cell does not as yet in every case render the poisonous action possible. If, for example, tetanus toxin is injected into a frog kept at room temperature, it combines as in the guinea-pig with the cells of the central nervous system, but the frog does not become sick: the toxophore group is still weak, and still inactive at room temperature; but after the period of incubation its effect appears instantly as soon as the frog is warmed to about 30°C. The effect of the toxin will even then not appear if the toxin is not combined with vital cells or if it has not the power to unfold its harmful action upon these cells.

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[3]The construction of the large molecule of living protoplasm is extremely complicated. According to Ehrlich it consists of a central atom-complex, to which the specific functions of the particular cell protoplasm are bound and which he designates as the functioning nucleus (*Leistungskern*). Numerous secondary "receptors or side chains" are joined to this one. The latter serve in the process of nourishment and in the metabolic processes by seizing the nutritional substances through specific chemical avidity, whereby the haptophore groups of the nutrient molecules and of the side chains (cell receptor) that are arranged one upon the other must be taken up. The conditions are therefore exactly similar to those existing at the union of the toxins to the "Leistungskern" by means of the side chains (Fig. 261).

Of the various antigens the toxins possess a comparatively simple structure, while on the other hand the protein molecules are decidedly larger. If they are bound by the side chains with the nucleus of serviceability (*Leistungskern*) the assimilation must be preceded by a disintegration into smaller fragments. For this purpose the side chain must furthermore possess an ergophore in addition to the haptophore group in order to accomplish the cleavage of the nutritive protein. Ehrlich compares this arrangement with the trap-hairs of the Drosera leaf, which digests the insects caught by the hairs by means of a peptic ferment. This same purpose is served by the arrangement which the side chains possess—not an ergophore group, but a second haptophore group—by means of which the ferments (complements) located in the blood and body fluids are seized and combined with the nutrient protein.

Ehrlich classifies the side chains according to their structure into three types:

1. Receptors (haptins), first order—the antitoxins. They have but one haptophore group.
2. Receptors (haptins), second order—precipitins and agglutinins, with a haptophore and an ergophore group.
3. Receptors (haptins), third order—complex lysins (bacteriolysins, hemolysin, etc., opsonins) with haptophore and complementophyl group.

Thus, for example, with the rabbit the tetanus toxin not only adheres to the cells of the central nervous system but also to other organ cells, likewise to those of the spleen. Upon this also depends the lesser susceptibility of the rabbit in comparison with the guinea-pig.

If no avidity exists between the receptors of the animal cells and the haptophore group of the toxin—in other words, if the toxin is not bound to the body cells—then the toxophore group is unable to act. Under such conditions the toxin is an entirely neutral substance with respect to the animal organism, of which the body takes so little notice that it does not even attempt to destroy it quickly (tetanus toxin in the turtle).

If the toxophore group of the toxins is destroyed so that its haptophore group remains uninjured, a substance is obtained which still is capable of uniting with a suitable receptor but which can no longer act poisonously. It is known as a *toxoid* (Fig. 261, 7). The *toxons* should not be confused with these, for they, like the toxins, are primary bacterial products and also possess the same haptophore group as they do, but can be distinguished from the toxins by a different, very much weaker toxophore group that also acts in a different way. The action of the diphtheria toxin is inflammatory and necrotic; the diphtheria toxon, whose action is decidedly chronic, produces the postdiphtheritic paralyses.

Fig. 261. Toxin and antitoxin. *1, "Leistungskern"* (*a*) with receptors (side-chains *b*). *2,* Toxin with haptophore group (*c*) and toxophore group (*d*). *3,* "Leistungskern" (*a*) with side-chain (*b*) on which is toxin. *4,* Overproduction of side-chains (*b*), which when free are referred to as antitoxin (*b'*). *5,* Binding or union of toxin with antitoxin (*b'*). *6,* Toxoid (*b''*) toxophore group destroyed, haptophore group preserved. *7,* Ricin, haptophore group (*h*), toxophore group (*c*), ergophore group (*e*).

The union of the toxin with the susceptible cell can not be dissolved by indifferent extractive agents, as can be done without difficulty with the alkaloids, dyes and antipyretics that are fixed only by physical forces. The union of toxins and body cells can therefore be conceived of as a chemical[4] union, depending on mutual affinities. But since the chemical constitution of neither the haptophore group of the toxins nor of the receptors of the *"Leistungskern"* is known, the union of the two can not be expressed by a chemical formula equation. We must content

[4]In the fixed chemical unions, which the toxins and other antigens undergo with the protoplasmic molecule, we discern the reason why they alone are capable of exciting the development of antisubstances while this property is not possessed by the more loosely combined alkaloids, dyes and antipyretics.

ourselves with expressing the union figuratively. The configuration (grouping of the radicals) of the receptors can vary, as shown in Fig. 261, 1. Only such toxins will be able to hold on to such receptors whose haptophore group fits the receptor as a key fits its own lock. If the cell does not succumb to the action of the toxin, it will attempt to relieve itself of the toxin which is firmly anchored to the receptor. That can be accomplished only if it rejects the toxin plus the receptor. The defect caused by this act is not merely remedied by the formation of a new similar receptor, but an overproduction of many similar receptors occurs. Such an overproduction in the living animal body can often be observed, and it also occurs in a similar manner with the formation of a callus. Here also the defect between the two ends of the broken bone is not only remedied by a newly developed bone mass, but an overproduction takes place which must be removed later on. The receptors, of which there has also been an overproduction and which the cell does not need, are afterwards removed and even rejected into the body fluids (blood, lymph). If such a rejected receptor comes in contact with a free toxin molecule they unite, thus making the toxin harmless; for a toxin whose haptophore group has been neutralized can form no new union with a receptor, no matter whether it be free or still firmly united with the body cell. These free receptors, which make the toxin harmless solely by a neutralization of the haptophore group (the toxophore group remains unchanged), are called *antitoxins, antidotes* (*side-chains, hatpin of the first order*) Fig. 261, 3-5. By repeated careful treatment (immunizing) with nonfatal quantities of toxin the production of large numbers of specific receptors can be brought about, which pass as so-called antitoxins into the blood and into the serum obtained from the blood. This antitoxic serum not only acts with animals that have previously been treated with toxin (actively immunized) but also with other animal organisms of the same and other kinds, with a neutralizing effect upon the same free toxin. Upon this depends the application of antitoxic sera for protective and curative inoculation (Ehrlich, Behring) and the antitoxin may even partly tear loose the toxin that is already loosely bound to the cells of the animal organism and then bind it again.

The development and action of antitoxins are purely specific. Thus the diphtheria toxin will produce only the development of a diphtheria antitoxin, which for its part will fix only the diphtheria toxin but no other toxins.

The action of every antitoxin depends only upon a neutralization of the haptophore group of the toxins. The toxophore group remains unchanged. The neutralization of the toxin by the antitoxin follows the law of multiples. If 1 cubic centimeter of an antitoxic serum neutralizes 100 fatal doses of a toxin in vitro, then 300 such poisonous doses become inactive through 3 cubic centimeters of this serum.

The nature of antitoxins is unknown. They may be proteins. They are susceptible to acids, light, heat, etc., but more resistant than the toxins.

The disturbances that have often been seen to appear after the use of antitoxic sera, e. g., the diphtheria curative serum, are not to be traced back to the antitoxin, but to the foreign proteins that are present in the serum (see under Anaphylaxis). Since the body soon excretes heterogeneous proteins, antitoxins that are injected with heterogeneous serums likewise soon disappear (in about one month), whereas antitoxins injected with homogeneous serums maintain themselves for a long time within the organism. One unit of the antitoxin, the so-called immunity unit (I. U.) is that quantity of antitoxin which neutralizes 1 cubic centimeter of the normal poison, namely, 100 toxin units. If this quantity is present in 1 cubic centimeter of serum, this serum is called a "simple" one.

The most important toxins are the following:

1. The diphtheria toxin of the *Bacillus diphtherae.* It kills experimental animals with the same symptoms as do the living bacilli. In addition to the toxin, toxoid and toxon (see page 342) are also known to exist.

2. The tetanus pasmin (toxin), the product of *Bacillus tetani,* is distinguished by an enormous poisonous action. A fatal dose for the human is less than 0.00023 gram. It usually unites with the central nervous system, and the transportation thither does not take place through the blood and lymph channels but through the axial cylinders of the nerves, which can again only take up the toxin in the muscle-end apparatus and conduct it centripetally (apart from whether the poison is injected directly into the nerves or into the central nervous system). This explains the long period of incubation, which becomes just so much longer as the nerve course is longer. With the mouse it lasts at least 17 hours, with humans four or five days. The poison can be prevented from reaching the central nervous system by intersecting the nerves or by an injection of antitoxin into the nerves. Its progress can also be checked in the spinal cord by an intersection. A poisoning of the brain does not result with such animals. Although the tetanus toxin is very easily rendered harmless with tetanus antitoxin before the poison has entered the nerve course, it is very difficult to release the toxin again by means of the antitoxin after it has become fixed to the nervous elements, namely, to cure tetanus.

The union of the toxin becomes more fixed as time progresses. and the activity of the serum less, as has been shown by the tests made by Doenitz. Doenitz found that the same quantity of antitoxin that, when injected simultaneously with toxin, protected a rabbit from a frequently fatal dose (of toxin) failed completely when it was injected four minutes after the toxin was injected (both intravenously injected). After one hour 40 times the quantity of antitoxin was necessary; after five hours a dose 600 times as great failed. The cause of the limited activity of the antitoxin is partly because the antitoxin can not follow the toxin in its course through the nerve track.

3. The blackleg toxin. Not all, but only some species of the blackleg bacilli form toxin.

4. The pyocyaneus toxin of *Bacillus pyocyaneus;* little investigation.

5. The hemolysins of *Bacillus tetani* and *B. pyocyaneus* as well as of the *Staphylococcus pyogenes* are true toxins, whose action extends to the red blood corpuscles, which they dissolve, which therefore act hemolytically. The bacterial hemolysins are considered as homogeneous substances, which therefore do not consist of amboceptor and complement (page) as do the specific hemolysins of animal origin that result from the introduction of heterogeneous red blood corpuscles and also appear in normal serums. The same is true of leucocidin of staphylococci, which kills and dissolves the white blood corpuscles (leucocytes) as well as several other cells such as hematoblasts, ganglion cells, etc. It should also be considered as a true toxin which gives occasion for the development of antitoxin.

6. The botulism toxin, which Van Ermengem first demonstrated in the filtrate of cultures of *Bacillus botulinus,* is distinguished by exceedingly poisonous activity. For humans 0.000035 grams are fatal. As with all toxins, the action is purely specific and extends to the nervous system. It is easily made inactive by outside influences (air, light, higher degrees of temperature, about 3 hours at 58° C., alcohol, ether, etc.), but on the other hand is not harmed by the gastric and small intestinal juices, nor reabsorbed by the digestive apparatus, as most other toxins are (Van Ermengem and Forszmans). Therapeutic treatment with antitoxic serum is promising only if given soon after the incorporation of the toxin (about 12 hours), the same as with tetanus toxin.

7. Toxin of the bacilli of the paratyphosus B-enteritidis group (the usual meat poisoners) that remains constant at boiling temperature and with gastric juice.

8. Vibriolysin of various kinds of vibrions, etc.

It is very doubtful whether the bacilli of anthrax, Asiatic cholera, typhoid fever, etc., produce true toxins. With the tubercle bacillus the opposite is practically certain.

The *zoötoxins*, e. g., snake venoms, toad poison (phrynolysin), scorpion poison, etc., correspond almost perfectly with the bacterial toxins. The only difference worth mentioning is that the period of incubation is exceedingly short with snake venoms in comparison with the bacterial toxins. On the other hand a complete conformity with the bacterial toxins is offered by the following four *phytotoxins:* Ricin from the seed of *Ricinus communis*; abrin from the jequirity bean (*Abrus precatorius*); crotin from the seed of *Croton tiglium*, and robin from the bark of the acacia, *Robinia pseudacacia* With regard to ricin it is remarkable that it possesses, in addition to the haptophore group, not only a toxophore group, but presumably another second ergophore, namely an agglutinophore group; therefore, figuratively expressed, the structure as shown by Fig. 261, 7.

The *snake venoms* contain various specific toxins—one hemolysin that dissolves the red blood corpuscles, and a neurotoxin that acts upon the nervous system. Both occur in the poison of the cobra. Also the hemorrhagin that attacks the endothelial cells of the vascular walls and that is present in the poison of the rattlesnake (*Crotalus*). All the toxins that have been mentioned are present in the venoms of the moccasin and copperhead snakes.

The dog is only slightly susceptible to snake venoms; the hog, the hedgehog and the mongoose (*Herpestes*, a small marten-like viverrine mammal of the Antilles) are almost refractory (nonsusceptible.)

The snake hemolysin differs from the bacterial hemolysins, which correspond exactly in structure to the bacterial toxins (Fig. 261, 2), but resembles in this respect the complex serum hemolysin. Like it, it consists of amboceptor and complement. Lecithin, stabile upon heating and present in the blood of mammals, serves as a complement to the snake hemolysin. On the other hand the chemical nature of the thermolabile serum hemolysin complements is not yet known. As an antidote against the activation of the lecithin of snake hemolysin we have cholesterin, which also breaks up the hemolytic action of saponin, but has no effect upon the serum hemolysin.

We can immunize actively against the toxin of snake venom, also passively by means of the antitoxic serum thus secured (antivenin against cobra venom). These particular sera are of practical use in the tropics (India, Brazil.).

From the preceding we can conclude that the congenital toxin immunity either depends upon the toxin not possessing any avidity at all for the receptors of the particular animal organism under consideration (tetanus toxin immunity of poulty, histogenic immunity), or that the toxin becomes united with nonvital cells, or that the toxin really becomes united with vital cells but that the action of the toxophore group is broken up (frog) by outside conditions (e. g., temperature).

The acquired toxin immunity is conditioned by the antitoxin which neutralizes the toxin and thereby makes it harmless. It can thus be distinguished from the acquired resistance against poisons which are not toxins, as alcohol, mineral poisons (e. g., arsenic) alkaloids (e. g.,

morphin, nicotin, etc.). It is known that it is possible to become accustomed (habit) to the last-named poisons, and that doses can be endured which would be fatal under normal conditions. This resistance against poisons can not be transmitted from one individual to another, as is the case with toxin immunity. It is bound more firmly to the tissues and it is therefore called a histogenic resistance to distinguish it from the "humoral" toxin immunity.

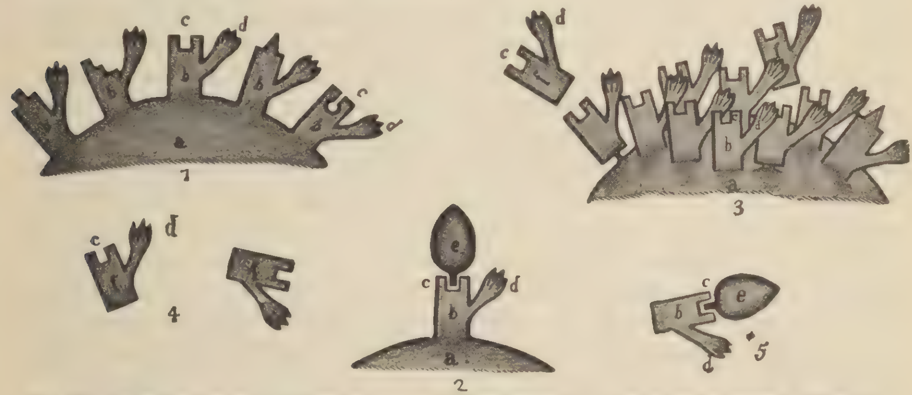

Fig. 262. Precipitation and agglutination. *1*, "Leistungskern" (*a*), side-chains second order (*b*), *c*, haptophore, *d*, ergophore group. *2*, Binding of precipitinogen (agglutinogens *e*) on side-chains; *a-d*, same as in *1*. *3*, Overproduction of side-chains, second order, which when free are referred to as precipitins or agglutinins as the case may be (*f*). *4*, Precipitin or agglutinin (*f*), *c* and *d*, as in *1*. *5*, Precipitinogen with precipitin *b-e* as in *2*.

III. The Precipitins

The precipitins (coagulins) cause a settling (precipitation) of dissolved proteins. Their development and activity is extremely specific.

The manner in which the precipitins act is very different from that of the antitoxins. While the latter depend solely upon a neutralization (binding of the haptophore group of the toxin (haptin first order), precipitation is as yet not accomplished by the binding of the haptophore group of the precipitins to the haptophore group of the protein that is to be precipitated (precipitinogen), but is induced or caused by means of a second ergophore or zymophore group of the precipitins (haptin second order, Fig. 262, 4). The precipitin shows much conformity with the toxin in structure, action and behavior. The haptophore group of the precipitins is also fairly constant and stabile, while the ergophore (zymophore group is very labile. By raising the temperature to 50-60°C. the latter become inactive and the precipitin is changed into the precipitinoid.

The precipitation requires the presence of electrically charged ions, such as are present, for example, in solutions of neutral salts. The precipitin does not unite with its precipitinogen in the living organism; they exist independently, one beside the other. Union takes place only in vitro.

The development of the precipitins occurs in the living animal organism in a manner analogous to that of the antitoxins (page 343 and Fig.

262) and of all other antisubstances. The protein, which gives rise to the development of the precipitin is called precipitinogen (Fig. 262, 2). Only hetrogeneous proteins produce precipitins, and then only when they enter the body fluids as heterogeneous proteins, and this is generally the case only when they are embodied in an unnatural (parenteral) manner, namely, subcutaneously, intravenously, intraperitoneally, etc. If on the other hand heterogeneous proteins are eaten they are denatured and robbed of their specific characters in the digestive tract, then synthesized again during the resorption into homologous proteins from which the precipitinogenic action passes off. Only when disturbances appear in the disintegration of the heterogeneous character can heterogeneous proteins occasionally be reabsorbed, act precipitinogenically and when repeated produce anaphylactic phenomena.

Corresponding to the various natures of genuine protein (precipitinogens), depending on the kind of animal, there are just as many different precipitins. Thus, for example, the parenteral incorporation of beef protein into rabbits produces the formation of a beef protein precipitin, and that of horse protein the development of a horse protein precipitin. Special plant (phyto-) and bacterio-precipitins are also formed for plant and bacterial proteins, and these differ among one another according to the different kinds of precipitinogens just as the zoöprecipitins differ.

The action of a precipitin affects only the precipitinogen which caused its development, therefore a beef protein precipitin will precipitate only beef protein, but not horse or hog protein, etc. The development and the action of precipitins are therefore specific.

The law of specific activity of the precipitins is limited slightly by the law of relation. The precipitin obtained from an experimental animal that is far removed from the precipitinogen animal not only acts upon the protein of the precipitinogen animal but also upon the protein of the relatives; e. g., a sheep protein precipitin obtained from a rabbit will not only precipitate the sheep protein but also, even if generally somewhat more weakly, the goat protein. Such reactions of relationship also appear with horses, zebra, and ass protein, with the protein of humans and anthropomorphous monkeys, with the wolf, fox and dog proteins, with the protein of hares and rabbits, with the protein of mice and rats, with that of sea-lions and seals, with that of the hog and wild boar, etc. But even here complete specificity can be brought about by obtaining the precipitin from one of the related animals itself. Thus a precipitinogen of the ass transmitted to a horse produces only a precipitin of the ass protein. In this case the relationship reaction is lacking in the horse protein, since homologous precipitins are not formed.

The various proteins of the same species of animals can not be separated by precipitation. Thus the anti-kidney protein serum also precipitates liver protein. Even the albumins can not be separated from the globulins by precipitation. Only the protein of the eye lens holds a pecu-

liar position. This is not specific according to species but according to the organ. Therefore the anti-beef-lens serum not only precipitates the lens protein of the cow but also the lens protein of all other kinds of animals, but not the protein of other organs, neither of the cow nor of other animals.

Similar conditions also exist among the sexual cells. Proteins into which iodine, nitro, diazo and other groups have been introduced lose their specificity. An antiserum thus produced reacts in similar manner upon every protein changed in this manner, irrespective of the species of animal from which it originates. On the other hand the protein does not lose its specie character through extensive tryptic cleavage.

The precipitins are protein substances (euglobulins) against which antibodies, antiprecipitins, can again be formed. The leucocytes and endothelium of the blood vessels take part in the formation of the precipitins.

The precipitins have attained a vast scientific and practical importance, as they have made it possible for us to prove and to identify the origin of protein. They are also useful, among other things, in bacteriological and clinical diagnosis, quite analogous to the agglutinins. Very useful results can be obtained with the precipitin reaction in determining glanders, infectious abortion, and above all with the thermo-precipitin reaction according to Ascoli in anthrax, blackleg and erysipelas. If little use is made of the precipitin reaction it is because the material for this procedure, which requires dissolved bacterial cell protoplasm, can be procured only with difficulty and by troublesome methods. The specific precipitin reaction is more useful for meat inspection, milk tests and medical jurisprudence to determine the origin of meat, milk and blood. In this case the difficulty of procuring the necessary protein solution ceases. The precipitin reaction has also become a useful method of research in physiology, biology, etc.

The practical application of the precipitin reaction is briefly as follows. More detailed descriptions are contained in the Manual of Food Analysis by Beythien, Hartwich and Klimmer, Vol. 3, page 129, etc., as well as in the Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine, edited by Klimmer and Wolff-Eisner.

1. Obtaining specific precipitating sera: Inject into one or preferably several experimental animals (e. g., rabbits) that genuine protein against which it is desired to obtain the precipitin. For the purpose of meat inspection and medical jurisprudence it is customary to use the blood serum of the animal in question, and in order to produce specific "lactosera" the milk of that particular kind of animal is used, the milk being obtained as free from germs as possible or having been sterilized with chloroform. The injections are usually made subcutaneously (about 5-10 cubic centimeters), sometimes intraperitoneally (about 5 cubic centimeters), less often intravenously (½ cubic centimeters). Each method of application offers advantages and disadvantages. According to Schur, an intravenous injection of 5 cubic centimeters serum repeated twice with an interval of one month is sufficient. Usually, however, several injections at intervals of 4 to 6 days are given (according to the recovery the experimental animal makes from the previous injection). Blood is then taken about 10 days after the last injections from the experimental animal that has previously been treated. The animals upon which the experiment is being made are allowed to fast 12 to 24 hours before the blood is taken, in order to procure

a clear serum. The blood that has been drawn is allowed to coagulate. The blood clot contracts and presses the serum out. The serum is taken off and eventually cleared by centrifuging. The clear serum into which the specific antisubstance (precipitin) passes is treated with phenol (5 per cent) or with a mixture that contains 5.5 per cent carbolic acid and 20 per cent glycerin, in the proportion of 1:10 parts of serum, and is thus preserved for a short time, or by drying for a longer time. The dried serum should be dissolved again with sterile water (1:9) before using.

2. Preparation of the test fluid.

(a) The milk whose origin is to be determined is diluted with 40 times the amount of a physiological sodium chlorid solution and is then ready for use.

(b) The test fluid from meat is prepared in the following manner: Leach with frequent shaking 1 gram of scraped fresh meat or 2 grams of smoked, pickled or sausage meat ground fine with 50 grams of a sodium chlorid solution (0.7 per cent) and phenol (0.5 per cent) for 24 to 48 hours at a temperature of about 10° C. (refrigerator); then filter the fluid till clear through a double filter (or at least till opalescent). The precipitation reaction usually fails with warm meat. The complement-fixation and the anaphylactic tests should also be applied here.

(c) Dried blood should be scraped off and extracted with the above-mentioned phenol-sodium chlorid solution.

3. Execution of the test. The test fluid is mixed with the specific precipitating serum. The ratio of both will depend on the strength of the serum. Usually 0.2-0.4 cubic centimeters of specific serum are used with 2 cubic centimeters of test fluid (diluted milk, meat or blood water). It is advisable to arrange carefully the blood serum and the test fluid in layers upon each other. The test materials are then allowed to stand quietly for 1 hour at incubating temperature or 2 to 12 hours at room temperature. If the test fluid contains the protein of the particular kind of animal which was used in the preliminary treatment of the test animals a fine, flaky turbidity or precipitate will appear. But if heterologous proteins (of a different species of animal) exist, no precipitation will occur. Control tests with homologous and heterologous protein should also be carried out at the same time. In addition to this it is advisable to make a control test of the test fluid without the addition of serum, another with serum of a rabbit not previously treated, and to prepare a further control consisting of the same amount of specific serum and 2 cubic centimeters of phenol-sodium chlorid solution without protein.

The thermo-precipitin reaction according to Ascoli has become of great practical importance in determining anthrax, blackleg and swine erysipelas. The great practical value of this procedure is that the precipitinogens are not destroyed by decomposition, which may last for months, while the anthrax bacilli in diseased carcasses die from decomposition within a short time (during the summer often in two or three days) and can not then be identified culturally or upon animal inoculation. In such cases anthrax may still be determined easily and definitely by the precipitin reaction. In swine erysipelas this reaction is not of as great practical importance, since the proof of the bacteria can not be established until long after death. (Concerning the technic of the thermo-precipitation reaction see Beythien, Hartwick and Klimmer's Manual of Food Analysis, Vol. 3, p. 134).

With anthrax and swine erysipelas the sick animals or the diseased carcass furnish the precipitinogen. The bacteria extract taken from the organs of the diseased carcass can be distinguished from animal precipitinogen by being stabile on heating. A highly potent anthrax or erysipelas serum is necessary for the test so that the clear, filtered extracts from the anthrax organs are at once made turbid, which can be seen plainly with the layer test. In addition to this, control tests with normal

serum are necessary. The normal serum must remain clear for at least a quarter of an hour. An extract obtained by cooking the spleen pulp of the animal suspected of anthrax is used as precipitinogen (test fluid). This extract is employed in five to tenfold volume of a physiological salt solution, which should be filtered before use through tissue paper or asbestos and then cooled to blood temperature.

The precipitin reaction has also attained importance as a clinical diagnostic test for glanders of solipeds, for abortion disease of cattle and cerebral spinal meningitis of humans, while similar attempts with typhoid fever, tuberculosis, etc., have been in vain.

With infectious abortion the animal suspected of having abortion disease does not furnish the precipitinogen but the precipitating serum which is mixed with a bacillary extract. We proceed in a similar manner with glanders. Furthermore it is often possible to produce an extract by cooking a lesion suspected of glanders and to test it with a "glanders-precipitating" serum. The precipitation that appears proves the glanderous nature of the change. Suitable controls should also be prepared at the same time. In like manner lesions of the placenta, etc., can be tested for abortion.

IV. The Agglutinins

Agglutinins cause cellular structures (bacteria, trypanosomes, blood corpuscles, spermatozoa, etc.,) which are suspended in a fluid to clump together (agglutinate), as a result of which any possible existing individual motility is lost. The agglutination does not kill the structures.

The phenomenon of agglutination may be observed with the naked eye as well as with the help of a microscope. In the first case we can see that the bacteria that were scattered uniformly through the fluid before the agglutination, and that cause a diffused turbidity of the medium, stick together in little clumps visible to the naked eye, due to the action of the agglutinin. In accordance with the law of gravity the clumps gradually sink to the bottom, the liquid simultaneously clarifying (Fig. 263). The clumps of bacteria that have sunk form on the bottom of the test tube a deposit that covers the entire bottom and also extends up the sides of the tube, showing a thickened, often jagged edge at the point where the bottom of the tube joins the vertical side walls. On the other hand, bacteria which, without having been agglutinated, have sunk to the bottom form a rounded (not flat), smooth-edged heap, but only in the deepest part (extreme bottom) of the test tube. If the sediment is shaken up slightly, the agglutinated bacteria rise in clumps while the nonagglutinated bacteria are again easily and uniformly scattered throughout the fluid.

On microscopic examination of the agglutination reaction the nonagglutinated bacteria are found more or less single. The latter show a Brownian molecular motion and in some cases also active motility. Agglutinated bacteria lie together in heaps, their motility lost. The macroscopic estimation is generally to be preferred to the microscopic. Coagglutination is less disturbing here.

The formation of agglutinins is stimulated as a result of the penetration or introduction of free cellular elements into the animal organism. The mere presence on the outer or inner body surface (e. g., digestive tract) is not sufficient for this purpose. They must actually penetrate into the tissues. An intravenous incorporation is generally most advantageous. The power of aggutination of a serum can become very

considerable so that even with a dilution of the serum of 1:1,000,000 and over agglutination can take place.

The formation of the agglutinins results in the same manner as that of the precipitins (Fig. 262), namely in the blood-forming organs with the leucocytes participating.

The living as well as the dead bacteria, their spores and their germ-free extracts cause the development of agglutinins. Agglutinins appear in the blood about three to six days after the bacterial infection, attain their greatest number after two or three weeks, and then very gradually disappear if new bacteria do not penetrate the body. It is taken for granted that all bacteria, even those that are not pathogenic, can lead to the development of agglutinins. The formation of agglutinins may, however, not occur if the animals lose much in weight or become greatly weakened by severe illness (acute infection).

The mode of action of the agglutinins corresponds to that of the precipitins. They resemble the haptins (side chains) of the second order, in which are distinguished an agglutinophore (ergophore or zymophore) group besides a haptophore group (Fig. 262, 4).

The development and action of the agglutinins are specific, like those of all antisubstances. Thus the formation of an agglutinin against Bacillus A can only be produced by the penetration of this bacillus into the living organism, but not by other kinds of bacilli, B, C, D, etc., and this agglutinin developed against Bacillus A acts only upon this Bacillus A and not upon Bacilli B, C, D, etc.

Agglutinins are present in the blood, serum, serous fluids, and in smaller numbers in the extracts of bloodless organs. A hereditary transmission of agglutinins does not occur and a placental transmission does not take place regularly. If agglutinogens penetrate into the fetus they can produce agglutinins. Only traces of agglutinins are excreted through the urine and tears, but very considerable quantities through milk (with infectious abortion).

The agglutinins are precipitated with the globulins during the precipitation (concentration) of the blood serum.

The agglutinins are comparatively resistant against light and decomposition. They become inactive at a temperature of 60-70° C. and are converted into agglutinoids.

Not only living bacteria but also those killed by heat or disinfectants are susceptible to agglutination.

The ability of the individual kinds of bacteria to become agglutinated varies greatly.

1. Those that can be agglutinated well are typhoid bacilli, various strains of *Bacillus coli*, microorganisms such as *B. enteritidis*, the so-called *B. suipestifer*, *B. paratyphosus* and dysentery bacilli, the bacillus of psittacosis, etc., the cholera vibrion and its relations, proteins, the bacilli of glanders and bubonic plague, Bang's abortion bacillus and *B. pyocyaneus*.

2. Less easily agglutinated are the anthrax, blackleg, tetanus, and tuberculosis bacilli; the staphylococci, streptococci, pneumococci and meningcocci, as well as yeast and thrush of mouth.

3. The least ability to be agglutinated is shown by Friedlander's pneumonia and mucosus bacilli.

With regard to the bacteria of the first group, agglutinins appear with ill and convalescent animals and humans; with those of the second group usually only after artificial immunization. No quantity of agglutinins worth mentioning can be obtained even artificially against the bacteria of the third group.

I II III IV

Fig. 263. Agglutination. I, Freshly prepared test in which the fluid is uniformly turbid. II, Beginning agglutination, fluid floculently granular. III, Negative agglutination. Fluid remained turbid; some bacteria settled to the bottom and formed button-like precipitate on bottom of tube. IV, Positive agglutination. Fluid is clear. The bacteria form the characteristic precipitate on the bottom of the tube.

But even among those species of bacteria that can be agglutinated easily there are types that agglutinate with difficulty. The best known example of this is the typhoid bacillus, which ordinarily is easily agglutinated. I have made similar observations with regard to the glanders bacillus. Continuous cultivation on artificial nutrient media of species of bacteria that are not easily agglutinated usually increases their agglutinability after a few passages and reaches the usual height of that particular species of bacteria.

As has been previously emphasized, agglutinins against many bacteria are not formed until the appearance of the particular bacteria in the (animal) organism. Nevertheless agglutinins against certain bacteria are found in the normal blood serum. Thus normal horse serum will occasionally agglutinate in a dilution of 1:100 to 1:300 glanders bacilli,

seldom at 1:500; normal human serum 1:30 typhoid bacilli, 1:50 *Bacillus coli* and 1:100 staphylococci; normal guinea-pig serum 1:40 anthrax bacillus, and normal beef serum 1:30 Bang's abortion bacillus, etc.

The law of specificity of agglutination suffers a certain limitation through the law of relationship. Very often the agglutination is in itself not specific, but only the degree to which it takes place (relative specificity). In these instances the agglutination extends not only to the bacillus that causes the agglutination (agglutinogen) but also to its "relatives," therefore there exists a group agglutination or coagglutination.

Coagglutination is explained as follows: The agglutinin should not be conceived of as a homogeneous body but consists of numerous individual agglutinins, which correspond to similar components of the agglutinogen substances of the bacterium. If the first are designated as A, B, C, etc., and the latter as a, b, c, etc., then the agglutination conditions of two closely related bacilli, I and II, can be explained somewhat in the following manner:

Bacillus I possesses the agglutinogen receptors a b, c, d, e,	Bacillus II b, d, f, g, h.
The corresponding sera contained upon immunization with Bacillus I the individual agglutinins A, B, C, D, E,	With Bacillus II B, D, F, G, H.

The immune serum Bacillus I acts with all its individual agglutinins A, B, C, D, E upon the corresponding agglutinogen receptors of Bacillus I, a, b, c, d, e; therefore the agglutination gives a maximum effect. On the other hand, only the individual agglutinins B and D of the agglutinogen components possessed in common by Bacilli I and II can become active during the action of this immune serum upon Bacillus II, therefore the value of the agglutination to Bacillus II must be less and will appear only in stronger serum concentrations. The same constituents of the immune sera of Bacillus II cause the reverse, a decreased coagglutination of Bacillus I. In case of a Bacillus III which possesses in common only the component d, the action of both sera is still more limited and appears only in strong concentrations. From this we can conclude that the immunizing bacteria of the serum can be agglutinated only in a maximum dilution if the ability of the bacteria and their individual species to agglutinate differs.

The individual agglutinins of an immune or disease serum which correspond to the agglutinogen components of the immunizing (or infecting) bacterium group are called the main agglutinins. Those that correspond only to the receptors of the particular bacterial species are known as the partial agglutinins.

Coagglutination can be overcome by removing the main agglutinins with the disturbing bacterial species by neutralizing the serum (Castellan test). Only the partial agglutinins which show complete specificity then remain.

The fixing of agglutinins and of substances that can be agglutinated does not result in constant proportions as with toxins and antitoxins, but the bacteria absorb in a strong agglutinin solution the many hundredfold multiple of that in weak solution. But the union is not permanent. They will again give off agglutinins from their surplus to solutions poor in agglutinins.

The presence of neutral salts is necessary to bring about agglutination. Agglutination should be considered as a physical process in which the surface tension is changed as a result of the union of agglutinins and agglutinogens, and the substances capable of agglutination are made to stick together by the presence of electrically charged ions (dissociated neutral salts). It corresponds to the colloids agglutinating into flakes. Bacteria are not only agglutinated into flakes by agglutinins but also by acids (acid agglutinins), alkalies, salts, certain dyes (chrysoidin), etc. This precipitation is of course not specific. Some kinds of bacteria are so susceptible to salts that even a physiological solution of sodium chlorid can agglutinate them into flakes (spontaneous agglutination). The susceptibility of the bac-

teria depends upon the kind of bacteria. Based upon this difference the acid agglutination can, for example, be used for differentiating, especially in the typhoid-coli group. The optimum of agglutination into flakes for typhoid bacilli exists at a concentration of hydrogen ions 4×10^{-5}, for paratyphoid with $16—32 \times 4 \times 10^{-5}$, for *Bacillus enteritidis* at $3 \times 10^{-4}—2.5 \times 10^{-3}$ and *B. coli* can not be agglutinated at all with acids.

Agglutination is of little or no importance to the living organism. No agglutination takes place within the organism. The development of agglutinins must therefore be looked upon as the expression of an infection reaction.

The practical and scientific value of the agglutination reaction is, on the other hand, very great. It serves chiefly for bacteriological and clinical diagnosis. Various kinds of bacteria (causative agents of abdominal typhoid fever, Asiatic cholera, etc.) can be determined and identified only with the aid of biological reactions, particularly by agglutination. For clinical diagnosis the agglutination reaction is used in determining abdominal typhoid fever of humans (Widal or Widal-Gruber reaction), glanders of the horse, infectious abortion of cattle, etc.

The serum of animals affected with glanders usually agglutinates glanders bacilli in a dilution of 1:1,000-2,000 and over, while the serum of healthy animals as a rule acts only in a dilution of 1:100—300. However, exceptions sometimes occur. Thus I once examined sera of healthy animals which still agglutinated in a dilution of 1:700 and even 1:1,000, and on the other hand sera of animals afflicted with glanders whose agglutination titer stood only at 1:400, 1:200 and even less. Of great value in this respect is the statistical record of observations made by Schutz and Mieszner, which is compiled in the following abstract:

Of 1911 horses free of glanders,
64.8 per cent showed an agglutination titer of 1:100-300
19.0 per cent showed an agglutination titer of 1:400
7.1 per cent showed an agglutination titer of 1:500
6.4 per cent showed an agglutination titer of 1:600
2.2 per cent showed an agglutination titer of 1:800
0.5 per cent showed an agglutination titer of 1:1,000
Of 298 horses suffering from glanders,
2. per cent showed an agglutination titer of 1:400
4. per cent showed an agglutination titer of 1:500
14.8 per cent showed an agglutination titer of 1:600
15.8 per cent showed an agglutination titer of 1:800
25.2 per cent showed an agglutination titer of 1:1,000
16.4 per cent showed an agglutination titer of 1:1,500
21.8 per cent showed an agglutination titer of 1:2,000 and over.

The agglutination titer is increased in healthy animals as well as in those suffering from glanders by means of a subcutaneous mallein injection, whereas the ophthalmic test is without effect on the titer.

The glanders agglutination reaction, discussed here as an illustration for the classroom, is carried out in the following manner:[1]

1. Preparation of the test fluid. Glanders bacilli are grown for one or two days upon glycerin-agar at a temperature of 37° C., are then killed by heating for one or two hours at a temperature of 60° C., then mixed uniformly with a sterile phenol-sodium chlorid solution (0.5 per cent phenol, 1 per cent sodium chlorid) to a slightly but distinctly cloudy suspension. The fluid is freed of the coarser flakes by filtering through a filter paper and is divided off into quantities of 2 cubic centimeters each into small, narrow test tubes.

2. Preparation of the serum solution. Blood (100 cubic centimeters is more than enough) is drawn under aseptic precautions from the horse that is being tested for glanders. A hollow needle previously boiled for 15 minutes is used, and the blood is conducted into a flask having a stopper (or other suitable vessel), both having been thoroughly cleaned and boiled (for 15 minutes). The tube is then sealed, and after coagulation the blood is sent into the bacteriological laboratory that conducts agglutination tests. There the serum, which has separated in the meantime, is removed, clarified by centrifuging and preserved with phenol (0.5 per cent). Forty times the quantity with the phenol-sodium chlorid solution mentioned above is then added.

3. Procedure of the agglutination test. To the test fluids divided into quantities of 2 cubic centimeters each in test tubes add enough of the diluted serum, which must eventually be diluted still more, so that the total will be in the proportions of 1:100, 200, 300, 400, 500, 600, 800, 1,000, 1,500, 2,000, 4,000 and 8,000 respectively. One test tube should be kept containing test fluid without addition of any serum. The tests are now kept at a temperature of 37° C. for 24 hours and then the agglutination that has appeared is determined (page 350). Some kinds of bacteria (typhoid, Asiatic cholera) are agglutinated more quickly at 50-55° C., but this is not true of staphylococci.

4. Judging the results. If a serum still acts, agglutinating glanders bacilli, at a dilution of 1:1,000, there is a positive reaction. If the agglutination titer amounts to 1:400 or less the reaction is negative. If agglutination appears at a maximum dilution of 1:400-800 the result is doubtful. If in addition the symptoms point toward glanders it is advisable to kill the horse. If, however, no definite glanders symptoms can be established the horse in question should be isolated and the agglutination titer of its serum tested again after three weeks. If the titer is still positive, it is advisable to kill the animal. If glanders has been established in one stable, then all the animals in the stable should be subjected to the agglutination test for glanders. The animals afflicted with glanders should be killed, the ones suspected should be isolated and a thorough disinfection of the stable, etc., instituted. Irrespective of the result of this agglutination test the remaining animals should again be subjected to the agglutination test after three weeks.

If glanders is again established proceed as above and continue tests at intervals of three weeks until the stable proves itself free of glanders on two successive tests. Concerning this see Schnuerer's Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine, edited by Klimmer and Wolff-Eisner.

Since the reliability of the glanders agglutination test is limited, it is combined with the complement-fixation test, precipitation test, etc.

The result of the agglutination test is determined by the serum dilution at which agglutination appears, as follows:

Bacilli	Positive	Doubtful	Negative
Infectious abortion	1:50 and over	1:40	1:30 and less
Glanders	1:1,000 and over	1:500-800	1:400 and less

The spontaneous precipitation of the agglutinated cells (bacteria, etc.) can be hastened by centrifuging and the time thus shortened. The bacteria that have not been agglutinated are in part also centrifuged out but can easily be scattered again by shaking, whereas the agglutinated ones can not be scattered uniformly through the fluid again. Spontaneous agglutination, i. e., the peculiarity of some species of bacteria to agglutinate into flakes in a simple sodium chlorid solution even without the addition of serum, is very disturbing.

[1]For further information see Manual on Food Analysis, by Beythien, Hartwich and Klimmer, vol. 3, as well as Schnuerer, Agglutination and Precipitation, in the Manual on Serum Therapy and Serum Diagnosis in Veterinary Medicine, edited by Klimmer and Wolff-Eisner.

V. The Complex Lysins

The complex lysins dissolve cellular structures. Distinctions are made as follows according to the nature of the cellular structures to be dissolved:

(*a*) Bacteriolysins — dissolve bacteria.
(*b*) Hemolysins — dissolve red blood corpuscles.
(*c*) Cytolysins or cytotoxins—dissolve or kill animal cells.

The law of specifity, previously referred to in connection with antitoxins, precipitins and agglutinins, can also be applied to the lysins. The specifity is even decidedly more developed with the lysins. It is well developed not only with regard to the kind of animal but also to the kind of cell. Thus the specifity of the nephrotoxin directs itself only toward the kidney epithelium, of the leucotoxins or leucocidins only toward

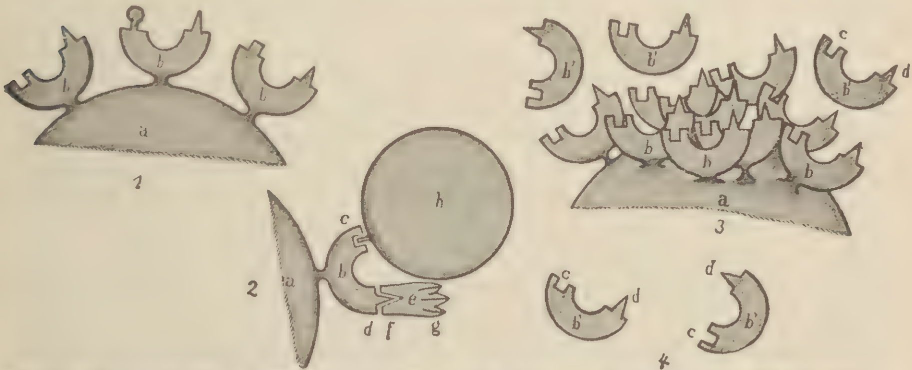

Fig. 264. Complex lysins. *1*, "Leistungskern" *a*, with side-chains (amboceptors or immune bodies) *b*. *2*, "Leistungskern" *a*, side-chains (amboceptors) *b*, with cytophil group *c*, to which the cell *h* is bound, complementophil group *d* with complement *e*, *f*, haptophore group, *g*, ergophore or zymotoxic group. *3*, Formation of immune bodies (amboceptors). *a*, "Leistungskern"; *b*, side-chains; *b'*, immune bodies or amboceptors with cytophilous (*c*) and complementophilous (*d*) group. *4*, Free immune bodies or amboceptors *b'*.

leucocytes and of the neurotoxins, hepatotoxins and pancreas cytotoxins only toward the cells of the nervous system, the liver and pancreas, etc.

The action of the complex lysins is not limited to formed protein bodies (cells) but applies also to so-called dissolved protein, which they continue to disintegrate.

As has been mentioned, the complex lysins dissolve cellular elements. With red blood corpuscles and several bacteria (cholera vibrions) this dissolution takes place in the test tube, but with most bacteria that are affected by bacteriolysis the animal experiment is necessary (abdominal cavity of living guinea-pigs, Pfeiffer's test, see below). If cholera vibrions are added to fresh cholera serum microscopic observations will show how the vibrions become motionless and almost melt down. The comma-shaped forms change into oval structures which soon melt together into little globules (granula). At first these are still refractive and can be stained with anilin dyes; they then lose these properties

and finally dissolve completely, especially in the fluid of the abdominal cavity of living immunized test animals, (guinea-pig).

Pfeiffer's test is accomplished by actively immunizing guinea-pigs against a particular kind of bacterium with dead bacteria, or passively with inactive or fresh immune serum. The (Asiatic) cholera vibrions are especially adapted to these tests. If now the same kind of bacterium (2 milligrams in 1 cubic centimeter sodium chlorid solution) is injected into the abdominal cavity of these living experimental animals, and if every ten minutes test samples are taken with a capillary pipette and examined under the microscope, the bacteria will be observed to lose their motility, then to melt into granula and finally to dissolve entirely. Pfeiffer's test proceeds strictly on specific lines and therefore is of practical use in identifying bacteria (cholera vibrions).

If the cholera serum is heated to 56° C. before using it, it loses in vitro the capability of bacteriolysis. Equally inactive is fresh, unheated normal serum. But if the fresh, unheated normal serum is added to the heated cholera serum, the latter becomes reactivated, i. e., it again attains the ability to dissolve cholera vibrions. From these observations the conclusion can be drawn that bacteriolysis depends on the combined action of two substances. They are (1) the amboceptor or immune body or intervening substance; (2) the complement (Fig. 264, 2). Only the immune substance (amboceptor) is formed during immunization. It is the carrier of the specificity of the complex lysins. The complement, on the other hand, is present from the beginning and is not increased during immunization. It is therefore present in the normal serum. The immune substance is no more capable of producing a dissolution alone than is the complement. The dissolution takes place only through the combined action of both.

The amboceptor is comparatively stabile; it can endure heating up to 56° C. for one-half hour, and prolonged, cool dark preservation in the presence of disinfectants (0.5 per cent phenol, etc.). On the other hand, the complement is very labile; it becomes inactive in vitro after a few days as well as by heating to 56° C. for one-half hour. A serum in which the complement has been made inactive, is designated as inactivated serum. The activity is restored by the addition of fresh serum that contains complement — the serum is reactivated.

The development of the amboceptor (immune substance) results in the same manner as that of the antitoxin (see above and Fig. 264, 3) and occurs in the spleen, lymph nodules and bone marrow.

Since the complement is not increased during immunization and its quantity is limited, the law of multiples (page 357) has a very limited validity with the complex lysins. Let us suppose that one loopful of cholera vibrion culture has just been destroyed through lysis by an immunity unit, then the double amount of serum can perhaps dissolve two loopfuls of cholera culture, but no greater amount of cholera serum will destroy more than 4 or 5 loopfuls of cholera culture. The surplus vibrions remain alive, multiply, and will kill the test animal in spite of the immune serum.

The law of multiples is also violated by the complex lysins, since the amboceptors, like the agglutinins, are not bound by stoichiometric conditions, but the union rather bears the character of an absorption reaction. With a surplus of serum the bacteria (etc.) absorb an indefinite multiple of the single dissolving dose. The affinity and the antigen action of several bacteria (e. g., cholera vibrions, but not typhoid bacilli), with regard to the amboceptors, seem to increase in virulence.

After a resulting bacteriolysis the union between dissolved bacteria and amboceptors is redissolved (falls apart), so that the amboceptors again become capable of action. A consumption of amboceptors does not seem to take place in the lytic processes.

The chemical nature of amboceptors and complement is not known. When separating by the addition of salts, the amboceptor, like the antitoxin, is deposited with the globulin. According to Pfeiffer and Proskauer, it is, however, not protein but a ferment. It can not, however, be dialyzed. Raising the temperature to 70° C. for one hour destroys it. It is very resistant against decomposition. The action of the complement is dependent on the presence of definite neutral salts.

Through dialysis the complement can be split up into two components (middle piece and end piece), of which one is precipitated with the globulins, while the other remains in solution.

The individual components are inactive and do not show lytic power until after their union.

The blood of the guinea-pig, particularly the arterial blood, is especially rich in complement.

The immune body (Fig. 264, 4) has, as the name amboceptor, chosen by Ehrlich, indicates, two "ceptors" (haptophore groups). The one, the cytophil group (*c*), serves for binding the cells that are to be dissolved; the other, the complementophil group (*d*) for the union of the complement (*e*), which at first produces the dissolution. The amboceptor therefore only makes possible (at room or blood temperature, but not in the cold temperature that follows) the union of the complement with the cells that are to be dissolved, but takes no direct part in the dissolution; it is nevertheless absolutely essential, since a direct union of complement and cell that is to be dissolved is impossible.

The complement, like the toxin, the precipitin and the agglutinin, has two groups, a haptophore (*f*), for binding to the amboceptor, and an ergophore (*g*), which Ehrlich has called zymotoxic because of its analogy to the toxin and enzyme activity. The zymotoxic group is entirely destroyed by the inactivation of the complement, by trifling chemical and thermal interventions, and thus the so-called complementoid is acquired.

The haptophore group, on the other hand, is maintained and can cause the formation of anticomplements during the immunizing process of foreign animal species either when the haptophore occurs as complement or complementoid. In the same manner incorporated amboceptors can produce anti-amboceptors with suitable animal species, which extend into the cytophilic group of the amboceptors.

It is worth noting that amboceptors can not only be produced against cells foreign to the body but also against cells (blood corpuscles) of similar animal species. If, for instance, the blood corpuscles of a goat are injected into another goat a hemolysin results which will dissolve the blood of the first goat but never (by virtue of a peculiar regulation) the blood corpuscles of the immunized goat itself. Such hemolysins are called isolysins.

In chemistry many analogies to these complex reactions are known. Thus the diazo group in the diazo benzoldehyde can unite with various

bodies, e. g., phenols, while its aldehyde group in turn can again enter into a series of unions, e. g., with hydrocyanic acid. Thus by means of the diazobenzaldehyde two substances (phenol and hydrocyanic acid) can be joined together in an analogous manner as is done by the amboceptor with the complement and, for example, the red blood corpuscles.

In the same manner that agglutinogens possess a complexity of the receptor apparatus and cause the development of chief and partial agglutinins (coagglutinins) and the latter cause coagglutination, so the lysogens (e. g., red blood corpuscles) also show a complexity of the receptor apparatus and cause the formation of dominant and side amboceptors (chief amboceptors and coamboceptors), the latter causing dissolution (e. g., the goat hemolysin for the codissolution of red blood corpuscles of the sheep). The difference between the chief amboceptors and the coamboceptors lies in the zytophilous groups of the amboceptors (Fig. 264, 4c).

We are also inclined to believe that the complementophilous group of the amboceptors as well as the haptophore groups of the complements do not always fully agree with one another but that here a limited complexity also exists.

This knowledge has been of practical use in Schreiber's erysipelas double serum (from horses and cattle), as well as in Sobernheim's anthrax serum. Since its practical use did not adequately meet expectations, the procedure was dropped. Today homologous serum is used most practically for the prevention of anaphylaxis among cattle.

The bacteriolysins are an important weapon of the animal organism in its fight against bacteria, such as cholera vibrions, typhoid, paratyphoid, enteritidis, coli and bubonic plague bacilli, spirochetes and trypanosomes. On the other hand, bacteriolysins have not yet been definitely demonstrated in the eradication of anthrax, swine erysipelas and tubercle bacilli, etc. The manner in which anthrax and erysipelas serums act is not yet definitely known.

The complex lysins in the complement fixation test are like the precipitins and agglutinins in that they are of great practical importance for bacteriological and clinical diagnoses, in establishing the origin of meat, milk, blood and foods.

The complement-fixation test offers the advantage over the precipitation test in determining the origin of flesh, etc., in that it is also applicable with boiled materials.

Concerning the technic of the complement-fixation test by Bordet and Gengou, which is used frequently in clinical (glanders, infectious abortion, syphilis — Wassermann's reaction) and bacteriological diagnosis and for determining the origin of flesh, etc., (see Beythien, Hartwich and Klimmer's Manual of Food Tests, volume 3, page 135). Here only the following is briefly to be noted:

For the *glanders complement-fixation test* we require:

1. The serum that is to be tested. It is freed of the complement and inactivated by heating for one-half hour at 56° C. If mixed with a 5 pen cent phenol-sodium-chlorid solution 9:1 it will keep for a long time if stored where it is cool and dark. If the horse has glanders its serum contains a glanders amboceptor, which is lacking in the serum of glanders-free horses.

2. Glanders bacillus extract (antigen).
3. Fresh guinea-pig serum, which furnishes the complement.
4. Inactive hemolytic serum, containing the hemolytic amboceptor.
5. Washed blood corpuscles from the kind of animal whose blood was used for producing the hemolytic serum. Usually blood corpuscles of the sheep are used; sometimes also of the goat or of other species of animals.

Procedure: Mix the serum to be tested with glanders bacillus extract and fresh guinea-pig serum. This mixture is heated for one hour at 37° C. (incubator) and is then treated with the so-called hemolytic system, consisting of inactivated hemolytic serum and sheep blood corpuscles. Whether hemolysis has set in can be determined after a renewed heating in the incubator. The hemolysis can be recognized by the color of the fluid, which changes from a dull, grayish red to a clear, blood red. If the hemolysis is complete a red sediment (consisting of red blood corpuscles) does not appear, but such sediment is usually more or less present with an incomplete hemolysis or when hemolysis is entirely lacking. If hemolysis is missing the clear fluid standing above the blood corpuscles is colorless.

The results obtained from the complement-fixation test can be seen in the following table and in Fig. 265.

	Case I, Horse Glanders	Case II, Horse Free of Glanders
The serum to be tested, inactivated	Glanders amboceptor.	No glanders amboceptor.
Fresh serum from the guinea-pig	Complement.	Complement.
Glanders bacilli extract (glanders antigen)	Receptor for glanders amboceptor.	Receptor for glanders amboceptor.
One hour at 37° C.	Complement fixed to glanders antigen by glanders amboceptor.	Complement remains free. Since glanders amboceptor is lacking, no fixation of complement to glanders antigen.
Addition of the hemolytic system:		
Inactivated hemolytic serum	Hemolytic amboceptor.	Hemolytic amboceptor.
Sheep blood corpuscles	Receptor for hemolytic amboceptor.	Receptor for hemolytic amboceptor.
One hour at 37° C.	Since the complement is already united with glanders amboceptor and glanders antigen, it can not occur in hemolytic system. No hemolysis.	Complement had remained free. It now occurs in the hemolytic system and produces hemolysis.

Like other immune substances (e. g., agglutinins), amboceptors also occur normally, even if only in small numbers, in the blood of non-immunized or infected animals. They are called normal bacteriolysins or hemolysins to distinguish them from the immune bacteriolysins and hemolysins that are abundantly developed through immunization. As a result of this, simply demonstrating the presence of amboceptors does not suffice for making a diagnosis, but it is necessary to determine their titer, the same as in the agglutination test.

With regard to the proportional quantities of the individual biological reagents and to the control tests which must be carried out in addition to the main test, see in Mieszner's chapter on complement-fixation, Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine, edited by Klimmer and Wolff-Eisner.

Complement fixation is sometimes referred to as complement deviation. That is wrong. Complement deviation, which was first observed by Neiszer and Wechsberg, depends, according to the authors, upon the fact that the complement in the presence of a surplus of amboceptors becomes bound to free amboceptors and will be diverted by them from those united with bacteria. With the addition of the hemolytic system the diverted complement enters into this and produces hemolysis, notwithstanding the presence of large quantities of bacteriolytic amboceptors, and thus stimulates a lack of bacteriolytic amboceptors in the serum concerned.

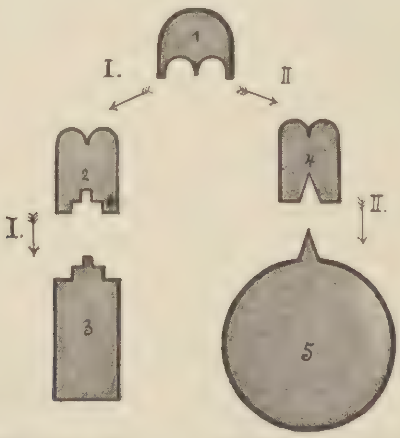

Fig. 265. Complement fixation in glanders. *1*, Complement; *2*, glanders amboceptor; *3*, glanders antigen; *4*, hemolytic amboceptor; *5*, red blood corpuscle. Case I: Horse is glanderous; complement unites with glanders amboceptor and glanders antigen—no hemolysis. Case II: Horse not glanderous; glanders amboceptor is lacking; complement unites with hemolytic amboceptor and blood corpuscles—hemolysis.

The complement can also become united through nonspecific absorption to various substances that bear a relation to the serum, and thus become inactive. Thus the complement could be fixed by shaking fresh serum with suspensions of bacteria, yeast fungi, aleurone, cotton, flax, slime from carrageen moss, etc. Such nonspecific complement fixation must be given consideration in the Bordet-Gengou test. The nonspecific complement fixation has been of practical use in the Wassermann reaction for syphilis. Probably this is a matter of dealing with lipoid-like substances that fix the complement with obscure reaction bodies that are present in syphilitic (leprous and scarlet fever) serum. Sometimes complement fixation fails to diagnose glanders, as is known to occur in the serums of some asses, mules, donkeys, and sometimes, although very seldom, in horse serums. These are able to fix the complement of their

own accord without the presence of glanders amboceptors and glanders antigen, and thus give the appearance of a glanders reaction. With such self-fixing of the serum it is advisable to apply the conglutination and K-H reaction (complement fixation and hemagglutination). There are also other ways in which complement fixation is not absolutely exact. To be certain as possible the complement-fixation reaction is combined with other serologic tests, such as agglutination, precipitation, and particularly with the ophthalmic mallein test.

The *conglutination test* shows many conformities with the complement-fixation test. Here also the inactivated suspected horse serum is mixed with glanders bacillus extract and complement, but in this case instead of taking guinea-pig serum fresh horse serum of a glanders-free horse is used. (Horse serum gives no self-fixation with horse complement).

The mixture is placed into the incubator (37° C.) for an hour; then a system is also added to recognize complement-fixations that are likely to occur. The system in this case also consists of sheep blood corpuscles, but inactivated hemolytic serum is not used as emboceptor, but instead an inactivated conglutinating serum is used. The latter does not dissolve the blood corpuscles but agglutinates (clumps) them. Beef serum is usually used as conglutinating serum.

Such self-fixing sera can also be successfully examined with the aid of the K-H method (complement-fixation and hemagglutination), and used with the red corpuscles of the guinea-pig instead of with those of the sheep. Naturally a hemalysin that will act against these blood corpuscles must then be used; normal inactivated cattle serum is used for this purpose. Fresh serum obtained from a horse not afflicted with glanders serves as complement. If the serum that is to be tested comes from a nonglandered horse it will not fix the complement to the glanders antigen; hemolysis will appear. But if, on the other hand, the serum to be tested comes from a glandered horse, the complement is united to the glanders amboceptor; hemolysis does not occur; the red blood corpuscles become agglutinated (hemagglutination) by the horse serum.

VI. Phagocytic Theory, Opsonins and Bacteriotropins

By phogacytosis we mean the ability of so-called phagocytes to ingest small foreign bodies as well as bacteria and to digest and thus to destroy them.

Panum and Roser were the first to express the supposition that the white blood corpuscles of the animal organism assisted effectively in the struggle to destroy pathogenic bacteria that had entered the body. This supposition later received experimental confirmation and development into the phagocytic theory through Metchnikoff's extensive experiments.

Metchnikoff first supported his phogocytic theory by his investigations of a gemmiparous fungous disease of the water flea (*Daphnia*). The infection of these ani-

mals resulted from the swallowing of the asci of that particular fungus. They were digested in the digestive apparatus and thus set free the inclosed, pointed spores. The latter bore through the intestinal wall and are then taken up and digested by the leucocytes attracted there. Under these conditions the animals remain alive. But if individual spores succeed in escaping destruction by the leucocytes the daphnias die from the general infection that attacks them. He was also able to observe the ingestion and digestion of anthrax bacilli by phagocytes in frogs into whose dorsal lymph sac he had injected anthrax bacilli.

Metchnikoff's phagocyte theory was further supported by work on the natural immunity of guinea-pigs against *Spirochaete obermeyeri*, streptococci, various yeast fungi and *tryponosoma lewisi*. The appearance of phagocytes was also established in rabbits that had received injections of spores and filaments of fungi, especially *Aspergillus* species. On the other hand the phagocyte theory was vigorously attacked, especially in Germany. The phagocytes were said to take up the microorganisms only after they had already been weakened or killed by other influences. The body fluids (blood, exudates, aqueous humor, etc.) are also able to destroy bacteria to a great extent and without the assistance of cells.

Today we take a reconciling position and grant phagocytosis great importance with certain infectious diseases (streptococcic diseases, etc.), while with other diseases (Asiatic cholera, bubonic plague, typhoid fever, etc.) it seems to exert little or no influence. With the latter the destruction of the disease bacteria can be traced first of all to humoral, bactericidal substances (complex lysins) (compare Pfeiffer's test, p. 370).

The phagocytes are not homogeneous cells. Formerly Metchnikoff divided them into microphages and macrophages. The first are almost identical with the mononuclear and polynuclear leucocytes of the blood and with the wandering cells of the connective tissue. The macrophages included the fixed cells of connective tissue having a large nucleau (granulation cells), certain vascular endothelium, the Kupfer's stellate cells of the liver, the pulp cells of the spleen and bone marrow. Recently Metchnikoff designates the microphages as mobile, active, the macrophages as fixed phagocytes. According to Metchnikoff the microphages are especially concerned with the destruction of microorganisms, the macrophages with atropic and resorption processes, and the absorption of animal cells, e. g., of injected, heterologous red blood corpuscles.

In phagocytosis the phagocytes are guided by their susceptibility (positive chemotaxis), entirely unconcerned whether phagocytosis results in harm or good for the combined organism. The process of phagocytosis is consummated in such a way that the phagocytes send out one or more runners which engulf the foreign body that is to be ingested (bacillus) and assist it into the inside of the phagocyte. A vacuole filled with a clear fluid forms around the bacillus. In the case of motile bacteria (*Bacillus typhosus, B. pyocyaneus, Vibrio cholera asiaticæ*) an active movement of the bacilli that have been ingested into the digestive vacuole can occasionally be noticed, which is proof that the bacteria are engulfed

[5]Metchnikoff, L'immunité. Paris, 1901. The numerous works of Metchnikoff are to be found in the Annales de l'Institut Pasteur.

[6]If Pfeiffer's test is undertaken on immunized guinea-pigs which are previously narcotized with tincture of opium, and, as Metchnikoff says, the leucocytes have been weakened, the test animals die. On the other hand, guinea-pigs that have not been immunized and that have had previous to the bacterial injection an injection of bouillon in the abdominal cavity to entice the phagocytes remain alive (Metchnikoff experiment). Based upon this observation Metchnikoff disputes the significance of the humoral bactericidal substances and sees the chief protection in the phagocytes.

by the phagocytes in a completely viable condition. Later on the movement of the bacteria ceases and the disease agents are killed by the phagocytes. They become pale, transparent and eosinophilic, disintegrate into granules, and are finally completely dissolved and digested. This process of dissolution covers various lengths of time with different bacteria. While cholera vibrions, capsule-free anthrax bacilli, etc., are destroyed rather quickly by phagocytosis, the tuberculosis and leprosy bacilli as well as spores can be identified for months in the cells of the phagocytes. In such cases the phagocytes limit themselves to checking the germination of the spores and the increase of the bacilli.

By no means can phagocytosis always be looked upon as a great blessing to the animal organism. No doubt phagocytosis very often aids in the spreading of the nonmotile tubercle bacilli along the lymph course, and frequently when the tubercle bacilli break into and are carried about in the blood stream the phagocytes may easily effect the transportation.

Metchnikoff traced the digestion of the bacteria to an intracellular enzyme of the phagocytes, and he even believed that this dissolution is caused by a complex lysin. According to Metchnikoff the phagocytes are capable of taking up fully virulent bacteria so that a preliminary weakening by humoral influences is not necessary.

Metchnikoff also traces natural as well as acquired immunity to phagocytosis.

The existence of acquired immunity Metchnikoff at first explained by an acquisition of phagocytosis as a result of an adaptation to the special weapons of the particular bacteria. Later he believed that it was a question of the development of particular immune substances that incited the phagocytes to phagocytosis which acted upon them and not upon the bacteria. He called them stimuli. This supposition is wrong. There are certain substances that incite the phagocytes, but these substances do not act upon the phagocytes but upon the bacteria, etc., and become fastened to them. They are called bacteriotropins[7] (Neufeld) and opsinins[8] (Wright), because they guide the phagocytes to the bacteria (positive chemotaxis) or prepare the bacteria for ingestion.

In 1903 Leishman and Wright worked out a method which made it possible to measure numerically the degree of phagocytosis incited by the serum and to use this value (the phagocytic numbers and their relation to the normal values of the serum, the phagocytic index) as a guide for an active immunization with killed cultures. Wright then advanced the hypothesis that a low index was the cause of the illness. In immunization the index must be forced up higher than the normal and thus effect a cure. Since the use of large doses of vaccine is accompanied by a lowering of the index (a negative phase which acts unfavorably upon the disease process), a control is necessary to prevent the index from sinking too low during the illness. It has been proved that the practical usefulness of the index determination is very slight, but it deals with interesting theoretical facts.

Certain foreign bodies (ink powder granules, certain bacteria, as tubercle and capsule-free anthrax bacteria) are absorbed by the phagocytes without the presence of serum (immune substances). This is called spontaneous phagocytosis. With other microorganisms (streptococci) their virulence has a decided influence upon spontaneous phagocytosis, and only the slightly or nonvirulent forms succumb to the action of the latter, while the fully virulent ones, even in a dead state, are resistant and are only made capable of absorption by immune substances (bacteriotropins and opsonins).

[7] τρόπος = turning.

[8] ὀψωνέω = to prepare for a meal.

Bacteriotropins are comparatively stabile upon heating and can resist a temperature of 60°C. for one-half hour. They will keep for years if preserved with phonol and stored in the dark. They act upon bacteria, with which they form a firm union. They develop in the spleen. According to Pfeiffer they are identical with the bacteriolytic amboceptor.

Phagocytes and immune serum need not originate from the same kind of animal for tests for bacteriotropins. Phagocytes from guinea-pigs, rabbits, etc., can be allowed to act upon serum from humans, horses, etc., and vice versa, without endangering the result. Leucocytes from rabbits or guinea-pigs are usually used as phagocytes. They are obtained by injecting sterile bouillon or aleurone suspensions into the abdominal cavity of the particular animal that is to be tested. Hereupon an exudation rich in leucocytes appears. The cells contained in this are freed from the exudation fluid by washing with a physiological sodium cholorid solution and moderate centrifuging. They remain viable for hours at 5-10° C. For the test mix 0.1 cubic centimeter serum (eventually diluted) with one drop of bacterial suspension (about one loopful of culture to 1 c.c. physiological sodium chlorid solution) and two drops of leucocyte suspension. After an incubation of 1½ to 2 hours smears are prepared, stained and examined under the microscope. Controls without serum and then with normal and standard serum are recommended.

The phagocytes often destroy the ingested bacteria, such as Asiatic cholera, typhoid, paratyphoid and dysentery bacilli, while tubercle bacilli and staphylococci are seldom harmed.

The *opsonins*, like the bacteriotropins, assist phagocytosis. But they are of a more complex nature, are inactivated like the complex lysins (p. 356) after heating for one-half hour at 56°C., and are reactivated by the addition of fresh serum that contains complement. Whether they are identical with the bacteriolysins is still an open question.

The opsonic tests are carried out as follows: Several drops of human blood are drawn from a puncture of the finger tip, are mixed with an equal quantity of 0.5 to 1 per cent of sodium citrate solution in physiologic sodium chlorid solution to prevent coagulation; they are then centrifuged, washed with physiologic sodium chlorid solution and refilled to the original volume. The serum that is to be tested is mixed in a capillary tube with equal parts of a red blood corpuscles suspension and bacterial emulsion, is kept at a temperature of 37° C. for one-half hour, is then worked down to a thin, uniform smear, and is fixed and stained. The 100 to 200 bacteria taken up by the leucocytes are counted and estimated to one leucocyte (phagocytic index). The phagocytic index is also determined in the control test with normal serum. The relation of the two constitutes the *opsonic index*. The work required for this is time-consuming and tiresome; the practical significance is slight; the procedure is hardly in use today.

VII. Anaphylaxis

By anaphylaxis[9] is meant the supersensitiveness acquired through parenteral injection of proteins of different origins (heterologous); that is, they did not enter the body by way of the digestive tracts.

The important features here are (1) that we are concerned with heterologous protein; it may be of animal, plant or bacterial origin; (2) that this protein enters into the fluid stream of the test animal as heterologous protein. This is done most safely by a subcutaneous injection, an injection into the abdominal cavity, blood stream, etc. On the other

[9] ἀναφύλαξις, without protection.

hand protein that is eaten is usually decomposed by digestive processes, is robbed of its heterologous character, and by absorption again built up into homologous protein. If, however, an overfeeding of heterologous protein takes place, an absorption of heterologous protein in the digestive tract may result, especially when digestion is weak, and thus cause the development of an oversensitiveness toward this protein.

The first parenteral incorporation of heterologous protein is not injurious to the animal in question if we are not dealing with poisonous proteins, but may lead to supersensitiveness — sensitizing.

If at the end of the period of latency another parenteral, intraperitoneal, and especially intravenous or intracardiac injection of the same protein follows, then anaphylaxis appears, i. e., an acute poisoning with typical symptoms that causes death within a few minutes (Richet, Arthur). It is advisable to be cautious with intravenous and intraperitoneal serum and blood injections in practice! They can easily cause the patient's death if repeated after two to three weeks or even after a longer interval. Such losses have often occurred when serum and blood vaccination of cattle were made against anthrax and foot-and-mouth disease.

The guinea-pig is particularly well suited for experimental purposes.

The sensitizing is done most easily by means of subcutaneous injection. The dose amounts to about 0.1 cubic centimeter with cattle serum, or 0.01 cubic centimeter with horse serum, but also smaller quantities, 1/100,000 to 1/1,000,000 cubic centimeter serum. Poultry and plant protein masses that can not be identified chemically will still act as anaphylactogen.

The reinjection should take place after three to four weeks by means of intracardiac or intravenous injections of about 0.01 0.1 cubic centimeter serum, etc. The supersensitiveness may last for three years. Protein of the same origin as used when sensitizing should be used for demonstrating anaphylaxis. Therefore the law of specificity also applies here. Upon this depends its practical application in determining the origin of meat, milk, vegetable substances, etc. When making the intraperitoneal reinjection four to six cubic centimeters of heterologous serum is necessary. The course is here retarded and does not produce death for almost an hour.

The symptoms of anaphylaxis following an intravenous injection are immediate stariness of the hair, discharge of feces and urine, spasms of the masticating muscles after one to three minutes, jerking and stretching of the back and leg muscles, forced respiration, later becoming retarded and intermittent. The blood pressure and temperature drop very quickly. A rise in temperature may also occur with very small quantities of antigen. Death follows after two to six minutes through suffocation while the animal is in the act of inspiration. The corneal reflex is maintained for some time. Upon postmortem severe inflation of the lungs is found, less often slight hemorrhages on the surface of the lungs. The tendency of the blood to coagulate is lessened. The leucocytes in the

circulating blood are decreased (leucopenia). If the animals do not die they recover quickly and completely. If the reinjection is made with 1/10 to 1/1,000 cubic centimeter intradermally, then as with the Von Pirquet tuberculin test a very small, very red, hot, abrupt swelling appears after about 12 hours, which reaches the height of its development after one to one and one-half days. With rabbits and guinea-pigs a necrosis of the surface and even deeper occurs at the point of injection.

The sensitizing substance is within moderate limitations stabile upon boiling. Accordingly the guinea-pig can be sensitized with an extract of cooked meat. This is of importance in the determination of the origin of fried or cooked meat, on which the precipitation reaction that is otherwise made use of fails if the heat has affected the inner portion of the meat. Native protein must be used for reinjection.

Related reactions (coanaphylaxis) are also observed in anaphylaxis as with the precipitation reaction, etc. The proteins of the crystalline lens and of the sexual cells occupy the same peculiar position with regard to the other animal proteins as in the precipitation reaction. Anaphylaxis like the formation of precipitins and complex lysins, is caused only by protein. The anaphylactic shock can be suppressed by hypertonic salt solution.

The supersensitiveness can be transmitted passively.

The poison that is formed from the reinjected protein during the anaphylactic shock is designated by Freidberger as anaphylatoxin. He also produced it in vitro by the action of immune serum upon the respective protein.

Serum sickness among humans and animals which appears after the injection of serum is to be looked upon as anaphylaxis; it runs its course with fever, swellings of the lymph glands, edema, pains in the joints, exanthema, and fortunately only seldom with anaphylactic shock. Hay fever, which depends upon poisoning from the pollen proteins of grasses, as also the tuberculin reaction with tuberculous patients is to be explained as anaphylaxis toward pollen protein or tuberculin respectively. Allergy (10) is often distinguished from anaphylaxis. By this is meant the changed manner of reacting, as is the case with tuberculous patients toward tuberculin, with glandered animals towards mallein, etc.

If an animal withstands an anaphylactic shock it becomes anti-anaphylactic; it then acts like an abnormal animal. But this condition lasts only a short time; after three days (with larger doses after several weeks) the animal returns to the anaphylactic state again.

VIII. The Aggressins

By aggressins (Bail) is understood the poisonous substances of bacteria, produced only in the animal body, which lower the resistance of the organism and thus make it possible for the bacteria to gain a foothold.

[10] ἄλλη ἔργεια, changed ability of reacting.

They render nonlethal doses of bacteria in the organism lethal and cause a severe course of infection by weakening the protective powers of the animal organism (phagocytes). If used with care and free from bacteria they produce an anti-aggressive immunity (Bail) which is particularly of practical importance against the so-called "true" parasites (*Bacillus plurisepticus*) with which an immunization is possible only when using living bacteria and this sometimes fails.

The Bail aggressin theory has been very much contested. According to present-day views the aggressins are identified with the endotoxins or the dissolved bacteria substances which can also be produced artificially in vitro by autolysis and extraction of bacteria.

IX. Protective and Curative Vaccination

The same biological processes that determine the character of immunity after an infectious disease has been withstood also takes place after vaccination with bacteria without the appearance of clinical illness.

In practice the following are used for vaccination:

1. Bacteria that have been killed, such as vaccine against bovine infectious abortion (Klimmer) glanters (Farase, Schering), cholera, typhoid, furunculosis, mastitis (streptococcus vaccine), etc. Apart from rare, nonspecific, local or general allergic reactions (local inflammation, fever, headache) there is no possibility of a specific illness resulting from the vaccination.

2. Living, attenuated or avirulent bacteria, as in vaccination against tuberculosis with avirulent tubercle bacilli (Klimmer), against anthrax, erysipelas and rabies (Pasteur), against smallpox (Jenner), against bubonic plague (Strong), against blackleg (Arloing, Cornevin and Thomas), against bradsot (Nielsen), etc.

3. Living, virulent bacteria, as in vaccination against contagious pleuropneumonia (Willems), sheep pox, cholera (Ferran). Vaccination with living, virulent bacteria is possible only if the microorganism causes a specific disease from a very definite source, whereas its transmission through other means produces no disturbances of health that are worth mentioning. Thus the cause of Asiatic cholera is pathogenic to humans only from the intestines but not from the circulation. The cause of contagious pleuropneumonia does not produce the disease if it is injected into the subcutis (of the tail). Smallpox virus as a rule will not produce such a severe general illness when inoculated into the skin as when it is transmitted naturally, because a partial immunization of the body is effected by the local process that develops following the cutaneous inoculation which suffices to prevent a general infection or at least to moderate it. There is always a certain danger of spreading the disease when working with living, infectious material, even if, as with 4, protective serum is used with it.

4. Living, virulent bacteria with protective serum, as in the simultaneous vaccination against erysipelas (Lorenz), against anthrax (Sobernheim), against hog cholera (Dorset, McBryde and Niles), serum-virus vaccination against sheep pox, against rinderpest (Koch and Kolle); also vaccination with sensitized vaccine by Besredka must be added here.

5. Immune serum. With exclusive serum inoculation animals receive passive immunity that lasts but two or three weeks. It therefore serves chiefly as a curative vaccination, as in tetanus, diphtheria and petechial fever. If the vaccinated animals are located in an infected area and thus exposed to the natural infection they may also take up living, virulent organisms in addition to the injected protective serum and thus become actively immunized. Following with the virus. Occasionally we content ourselves in special cases with the short, passive immunity, as against foot-and-mouth disease, when cattle are sent to exhibition, etc. Special attention should be called here to Jensen's calf scour serum which is used as a curative and also as a preventitive inoculation. Since newly born calves are susceptible for only a short time to the common causes of calf scour, the protective serum inoculation is sufficient in practice. According to their actions the sera are divided into antitoxic and antibacterial sera. To the first belong the diphtheria serum and tetanus serum; to the latter calf scour serum, erysipelas serum and anthrax serum.

6. Bacterial extracts. They likewise contain immunizing substances (antigens), even if in small quantities. Abortion by Schreiber is such a bacterial extract.

7. Dissolved celular substance and metabolic products of bacteria, such as exist, for example, in tuberculin and mallein. The immunizing action is slight with sick individuals and is lacking entirely in healthy individuals. Their chief value lies in their use as diagnostic aids (allergy).

For further particulars on preventive and curative inoculations see Klimmer and Wolff-Eisner, Manual of Serum Therapy and Serum Diagnosis in Veterinary Medicine.

D. Sources of Infection; Their Avoidance, Removal and Destruction (Disinfection)

The most important source of infection of the contagious diseases are the excreta of diseased animals. The bacteria contained in these can again produce an infection if they are taken up by suspectible animals. According to the location and nature of the infectious disease, this or that excrement proves to be the main carrier of the infectious substances. In glanders it is chiefly in the nasal and abscess secretions (skin); in rabies the saliva; in pulmonary tuberculosis the discharge from the lungs; in smallpox the cutaneous scales; in wound infections the pus; in vesicular vaginitis the vaginal discharge, etc.

It has been determined by numerous experiments that animals that are not noticeably sick, or that have recovered and are convalescing, harbor virulent infectious substances and can excrete them. Such carriers of bacilli have been identified in erysipelas, fowl cholera, etc.

Carcasses of the diseased animals should also be mentioned here. As long as they are not devoured by other susceptible animals they ought to play only a small part in spreading contagious diseases; but perhaps when such carcasses are not satisfactorily removed during the spread of ectogenic (miasmatic contagious) diseases, as particularly anthrax and blackleg, they are concerned in the dissemination.

Besides living sources of infection we must consider such articles as are soiled by the infectious excretions and which are generally known as carriers of infection, such as covers, blankets, parts of the harness, bandages, grooming utensils, etc., in glanders, foot-and-mouth disease and mange, as well as drinking pails, mangers and cribs in tuberculosis, glanders, etc. Occasionally other stable apparatus is concerned in carrying and transmitting infectious bacteria. Transmission of tuberculosis, swine-plague, contagious pleuropneumonia, glanders, foot-and-mouth disease, smallpox, etc., is made possible by stable air (so-called droplet or dust infection), whereas the air in the open, as a result of its constant changing, need not be considered as a general rule as a lasting source of infection. Furthermore, other intermediate carriers can cause indirect transmission; e. g., water, feed, bedding, etc., that are soiled by the excrement of diseased animals. Finally we should also mention in this connection the shoes, clothing and hands of persons.

In the case of ectogenic (miasmatic contagious) infectious diseases definite intermediate hosts must at times be considered as sources of infection (jointed animals in piroplasmmosis and trypanosomiasis), frequently the ground, less often the water. Therefore with most miasmatic contagious diseases the soil is the chief source of infection and in so far as it is rich in organic substances it contains certain causative agents of disease quite regularly (tetanus and edema); others, however, (bacteria of anthrax, blackleg, etc.) only when they have previously been brought there. This happens most frequently through infected animal excrement, diseased carcasses and certain waste of animal origin. The ectogenic disease that have the ability to multiply in the ground and even to develop spores there are, for example, in the case of anthrax, chiefly brought to the animals again with the feed.

I. Avoiding Sources of Infection

In combating infectious diseases the avoidance of sources of infection is of utmost importance. The ways and means than can be applied here must be determined by the various ways in which infection can occur with the individual infectious diseases. Thus much greater precautions can be observed by keeping the source of infection of tuberculosis distant than that of dourine or vesicular vaginitis. In general we can say that a more or less complete separation is necessary with the infectious substances that can be transmitted by the air, such as the causes of

foot-and-mouth disease, glanders, tuberculosis, contagious pleuropneumonia, sheep pox, etc.

It is advisable to remove the healthy animals from stables that they have been sharing with sick animals, which the latter have already infected more or less, and to stable them somewhere else. This is often impossible in practice because of outside reasons. One is therefore sometimes forced to carry out the segregation in a reversed manner by leaving the healthy animals in the stable and removing the sick ones, but of course first destroying scattered contagious matter with a satisfactory disinfectant. Occasionally conditions do not even permit such a separation, and it is then necessary to divide stable space into two divisions with a board partition. Since the wall that has been erected should divide the healthy from the sick animals, and especially prevent all possible communication between the two divisions, the partition should, if local conditions will allow it, not be provided with a door. The more expensive materials for the erection of a partition will be used only in case of a disease that requires a long period of isolation, as in the Bang method of eradicating tuberculosis. Sometimes one can help himself by housing the suspected animals in the stable of nonsusceptible animals, thus placing horses suspected of glanders in cattle barns, cattle suspected of contagious pleuropneumonia in horse stables, etc.

In keeping highly infectious substances distant from healthy animals it does not suffice merely to keep the animals separated, but care must be exercised at the same time that every possibility of carrying infectious substances from the sick animals to the healthy ones be prevented.

For this purpose it is advisable that the sick animals be cared for by different persons than those caring for the healthy ones and that communications be limited as much as possible among the attendants. Under no conditions should the attendants of healthy animals go into stables in which diseased animals on the same farm are housed, and above all not on other farms. If it is impossible to have separate attendants it is advisable always to attend first to the healthy animals and then to the sick ones, to put on over the other clothes a coat that is kept in the stables of the sick animals, other shoes, which should also remain there, and then after leaving this part of the stable to wash and disinfect the hands. In order to avoid disease germs from being brought in from disease-infected farms unauthorized persons should be forbidden to enter one's own stables even when there is no disease present, and especially such persons who are engaged on infected farms. During an epizoötic intercourse with butchers and cattle dealers, who according to experience frequently transmit foot-and-mouth disease, should be restricted as much as possible.

Wherever infectious material can be spread by grooming utensils, drinking pails and other stable implements great care should be exercised that the healthy animals do not come in contact, either directly or indirectly, with contaminated articles. Special implements should be used for the sick and for the healthy animals. If the animals are taken into the open they should be kept away from all places where they might contract infection. Here again precautions must be observed according to the nature and manner in which the infectious matter is excreted. With a highly contagious infection that is very easily carried and transmitted, e. g., the infections of foot-and-mouth disease and sheep pox, it is not only necessary to avoid immediate contact of the healthy animals with the diseased ones and their attendants on the street and in the field, but also to avoid the roads, meadows and fields upon which suspected and diseased animals have been passing, and to avoid communication between the herdsmen of both sides.

With infectious diseases that are easily spread by intermediate carriers (e. g., hay, straw, bran, manures, etc.) the greatest caution is advised in the purchase and the use of all articles that might serve as intermediate carriers. Finally attention is also to be directed to the fact that biting insects and ticks also transmit parasitic diseases. Non-biting insects (flies) can also carry disease germs into the bodies of healthy animals, to food, etc. The more rigid and careful one is in seeing to it that healthy animals avoid infectious substances the more certain will be the desired results.

Newly purchased animals (especially cattle) should always be looked upon as disease suspects. They should therefore not be put with the healthy stock at once but should be kept under quarantine for two to four weeks in a special place as a precautionary measure. This precautionary measure is also advisable even when the animals come from healthy stables, for opportunity is often afforded for contracting an infection during transit. Veterinary examination alone can not in this respect give sufficient guaranty against the introduction of disease, since it is known that after an infection has resulted (during the incubation stage) animals show no disease symptoms for some time, therefore appear perfectly healthy although they have already become infected. The animals should be watched carefully during quarantine, especially regarding liveliness, nasal secretions, drooling at the mouth, conspicuous coughing and difficult breathing, anorexia, diarrhea, discharges from genito-urinary tracts, nodules in the skin, severe itching, swelling of the legs and glands, as well as pains in the feet.

The provisions to be made to keep the infectious substances away from susceptible animals must be arranged according to the nature of the disease agents concerned and the manner in which infection takes place. Although very comprehensive and energetic precautions should be taken with contagious substances that are easily spread and also easily transmitted (as, for instance, sheep pox, foot-and-mouth disease, etc.), many precautions such as complete isolation can be omitted without harm in the case of "fixed" causes of infection. Thus it is sufficient in dourine, for example, to prevent coitus between the animals; in cowpox to avoid transmission by means of the milker's hands and by the cloths used in cleaning the udder, etc.

Since it has been proved that cattle owners often can not sufficiently protect their stock against the dangerous infectious diseases (epizoötics), *legal provisions* and precautions have been instituted to combat these diseases.

The German law relating to animal diseases requires the reporting of a number of diseases so that the authorities are notified of the occurrences of the particular disease and can order further precautions against it. Reportable diseases are anthrax, blackleg, bovine hemorrhagic septicemia, rabies, glanders, foot-and-mouth disease, contagious pleuropneumonia, sheep pox, dourine, vesicular vaginitis of mares and cows, mange of solipeds (sarcoptic and dermatocoptic mange) and sheep (dermatocoptic mange), swine plague (hemorrhagic septicemia) in so far as it is concerned with severe disturbances of the general condition of the sick animal, hog cholera, swine erysipelas including febrile urticaria (diamond disease), fowl cholera and fowl pest, and bovine tuberculosis recognized by outward symptoms in so far as it occurs in an advanced stage in the lungs or has affected the udder, uterus or intestines. In some parts of Germany influenza (pectoral form and se-

quelæ) of horses, cerebrospinal meningitis (enzoötic cerebrospinal meningitis, Borna disease) and encephalitis of the horse must be reported.

The duty to report rests with the owner, the farm manager or whoever has charge of the animals, also with the veterinarian, lay meat inspectors and persons who are industrially concerned with the removal, utilization or exploitation of the carcasses or their parts.

Furthermore import prohibitions are prescribed, for the remission of which legal support must be had. Examination is required of animals that are to be imported, and if there is danger of an epizoötic entering from a foreign country the revision and regular control of the stock farms within the boundary line are required. The law furthermore regulates the hanging of doors and gates of stables, farm premises, pastures, fields and inclosures, also restricts the use of pastures, public watering places, roads, etc., and the manner of utilization, exploitation and transport of sick or suspected animals and the products obtained from them and such objects as have come in contact with the sick animals. The law furthermore stipulates the arrangement of the isolation, guard or police observation of the diseased animals as well as of those suspected of having the disease or of having been exposed to the disease or suspected of having it, the killing of animals affected with or suspected of having the disease, the destruction of carcasses of animals that have died from a contagious disease, as well as their excreta and products and the objects contaminated by them (bedding, etc.), discontinuance of cattle and horse markets and public animal exhibitions, or the exclusion of certain cattle farms from the markets, the veterinary examination of the animals exposed to the disease in the locality or vicinity of the epizoötic, public announcement of the outbreak, and extermination of the disease, the disinfection of the stables, stalls and railroad stations used by sick or suspected animals, as well as of the dung from these animals, and the disinfection or safe removal of implements and other objects that have come in contact with them, especially the wearing apparel of such persons as have come in contact with the sick animals. If necessary the disinfection of the persons that have come in contact with diseased or suspected animals can be ordered. In times of danger from epizoötic or during the time that the epizoötic rages the police may order the cleaning of roads and stalls (stations, pens, public stables, market places, etc.), that have been used by diseased or suspected animals that have been brought together. Veterinary and police officials are charged with the execution of these precautionary measures.[11]

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[11]In the United States there are various Federal and State laws and regulations for the prevention and control of communicable diseases of animals. Copies of the Federal laws and regulations and a summary of State laws and regulations may be obtained from the Bureau of Aniand Industry, U. S. Department of Agriculture, Washington, D. C.—J. R. M.

II. Disinfection

By disinfection is meant rendering causative agents of disease harmless. This can be done by mechanical removal or by killing the disease germs. Usually the two procedures are carried out together by first mechanically removing infectious matter and then finally destroying such disease germs as may remain. Since those means that are employed in destroying infectious substances (disinfection in the narrow sense) act only to a limited depth, a preliminary mechanical removal of the infectious matter with all dirt, refuse, feces, etc., is essential.

1. The Mechanical Removal of Infectious Matter

Among mechanical means of removing infectious matter the following may be mentioned:

1. Cleaning with cold but better with hot water; in the latter case often with the addition of soap (soft soap), soda or lye. Hot 5 per cent soda or lye solution acts effectively in loosening certain kinds of dirt and can kill slightly resistant bacteria such as the bacilli of swine erysipelas and swine plague.

2. Dry sweeping. This is used frequently as a preliminary measure in stable disinfection. We must consider, however, that dry sweeping often creates dust, which includes the danger of scattering infectious matter. In modern methods of disinfection, dry sweeping is avoided when feasible and is replaced by the methods mentioned in 1.

3. Ventilation. This is not very efficacious even if assisted by beating, rubbing, etc. These latter again create dust which produces the particular danger of spreading the infectious matter.

4. Burial—only when the materials (manure, disease carcasses, etc.) contaminated with infectious substances are of slight or no value and can not be removed in any other way. Concerning the precautionary measures to be observed here, see page —.

2. Destruction of Disease Germs—Actual Disinfection

The number of means that can effect destruction of infectious substances and which we designate as disinfectants is extremely large. The requisites of a good disinfectant are certain, quick and safe destruction of the disease germs without injury to the objects to which they cling, and low cost of the entire disinfecting procedure.

The power of resistance toward the disinfectants varies with different disease germs. It is first of all dependent upon the conditions under which it is developed. Although the vegetative forms of growth (bacteria) are destroyed comparatively easily, the spores possess a much higher power of resistance. The disinfecting action is dependent upon a definite concentration of the disinfectant. In order to gain certain action the disinfectant must penetrate sufficiently through the material

that is to be disinfected. Chemical changes which weaken or break up the disinfecting action must not be allowed to take place.

a. Physical Disinfectants

1. *Sunlight.*—Sun rays as well as diffused daylight and strong artificial light (electric arc light, etc.) destroy bacteria and even spores. The time necessary for the action depends upon the intensity of the light, the kind of bacteria, the growth, etc., as the following examples show:

According to Pansini, pathogenic bacteria are destroyed by being exposed to the rays of the sun (Naples) in 1 to 1½ hours; anthrax spores in about 3 hours. According to Koch, tubercle bacilli that have stood at the window are destroyed in 5 to 7 hours. According to Buchner, *Bacillus coli* in the room are destroyed by the sun's rays in two days, *B.coli* in the open by sun rays in 4 hours, *B. pyocyaneus* in the open by sun rays in 6 hours. According to Dieudonné, *Bacillus prodigiosus* and *B. fluorescens* are destroyed by sunlight in March, July and August in 1½ hours, in November in 2½ hours, by arc light (900 normal candle power) in 8 hours, by gas light in 1 hour.

Only the (green), blue, violet and above all the ultra-violet rays of the sun's spectrum act bactericidally, whereas the red, orange and yellow rays are inactive. According to Dieudonné, the light causes the development of hydrogen peroxid in the presence of oxygen, and this only (not light as such) can effect the destruction of the bacteria. Buchner, Rapp, Thiele and Woolff, however, could not confirm this statement. According to Kruse, the destruction by light is dependent on the presence of oxygen (the destruction did not occur in hydrogen). Thiele and Wolff as well as Lombard are of the opposite opinion.

The destruction of bacteria by ultraviolet rays which are produced by the aid of the quartz mercury lamp has been used in a practical way in the sterilization of drinking water.

The Roentgen rays are ineffective against bacteria. The curative effect of Roentgen rays, e. g., in skin tuberculosis, can be traced back to changes that occur in the tissues under the influence of the rays.

Notwithstanding the value of the disinfecting action of light in nature, it can not be used in general in the practice of disinfection because its action reaches only to a slight depth.

2. *Desiccation* destroys some of the causative agents of human diseases (e. g., of gonorrhea, of Asiatic cholera in 3 to 5 to 24 hours) in a short time, but acts very slowly or not at all upon causative agents of animal diseases. Thus the tubercle bacillus withstands desiccation for weeks and months, the spores of anthrax and blackleg even for years. The disinfecting action of drying out is also substantially reduced under natural conditions by the fluctuation of the atmospheric humidity and the temperature, by the occurrence of hygroscopic substances in the disinfecting area, the inability to act at any great depth, etc. There is

therefore no assurance of a dependable action at long periods of time. Desiccation is not applied in the practice of disinfection.

3. *Low temperatures.*—The germs of disease as well as of putrefaction are not even destroyed by temperatures of 25° to 30° below freezing (—13 to—22° F.), even though they last for weeks, but are checked in their development by a slightly low temperature of 56°C. (41° F.—of practical use in the preservation of foods). Even the extreme low temperature of—130°C. (—202° F.) which destroyed anthrax bacilli in 20 hours does not destroy anthrax spores. The latter even remained fully virulent after 108 hours. I found tubercle bacilli that had remained fully viable and active after having been suspended in water and milk had been kept for 5 weeks at—5°C. (23°F.).

According to this the low temperatures that occur in the winter are not applicable in the destruction of germs. Kraus has given a comprehensive compilation of the life period of bacteria at low temperatures.

4. *Higher temperatures,* on the other hand, act more or less fatally upon bacteria and are used a great deal for disinfection. A real difference exists in the disinfecting strength of higher degrees of temperature since the bacteria are destroyed much more easily in fluids or in saturated steam than in dry media.

Thus, for example, tubercle bacilli that are present in liquids (milk) are destroyed at 55°C. (131°F.) in four hours, at 60°C. (140°F.) in one hour, at 65°C. (149°F.) in 15 minutes, at 70°C. (158°F.) in 10 minutes, at 80°C. (176°F.) in 5 minutes, at 90°C. (194°F.) in 2 minutes, at 95°C. (203°F.) in 1 minute, at 100°C. (212°F.) instantly.

If, for instance, only the bacteria are killed in a fluid, e. g., milk, it is called pasteurizing. Spores are not harmed at this temperature; the action of the temperature of 100° C. which lasts for minutes to hours is necessary for their destruction. If all germs, even the spores, are destroyed, then it is called sterilization. (Concerning disinfection by boiling, see page 406.)

Bacteria withstand dry heat much better than moist, saturated steam. Thus, for example, anthrax spores are killed by boiling 2 minutes (100° C., 212° F.), while with dry heat even 140° C. (274° F.) they are killed only after 3 hours. This remarkable difference is attributed to the fact that dry, warm air extracts water from protoplasmic protein and thereby makes it more difficult to coagulate.

As has already ben determined by Koch and Wolffhuegel, dry heat (hot air) will (1) destroy spore-free bacteria at a little over 100° C. (212° F.) in 1½ hours. (2) Spores of fungi and molds require an action of 1½ hours at 110-115° C. (230-239° F.). (3) Bacterial spores are not destroyed until after 3 hours' heating at 140° C. (274° F.). (4) With hot air the temperature penetrates slowly into the material that is to be disinfected. Even heating for 4 hours at 140° C. (274° F.) does not suffice for the disinfection of objects that are fairly voluminous

(e. g., horse blankets that have been folded together, a small bundle of clothes, etc.). (5) Many objects are injured by heating for 3 hours at 140°C. (274°F.).

Such sterilization can be endured without harm only by glass, metal and clay objects, as, for example chains, bits, etc.; while on the other hand enamel dishes, from which the enamel can chip, leather objects and organic substances can not undergo such sterilization.

The humidity exerts a great influence upon the destruction of bacteria by heat, which of course is of no practical importance. According to Ballner, diphtheria bacilli were killed at a temperature of 90° C. (194° F.) and a humidity of 10 per cent in 180 minutes, 20 per cent in 120 minutes, 30 per cent in 120 minutes, 40 per cent in 5 minutes, 60 per cent in 2 minutes, 80 per cent in 2 minutes.

Annealing should also be mentioned as a certain means of destroying disease germs. It is sometimes used to disinfect metal objects (iron chains, etc.).

Reference should also be made to the burning of contaminated objects having little or no value (manure, animal waste, diseased carcasses, etc.) which is frequently done to insure certain destruction.

5. *Steam*—an almost supreme disinfectant which was recognized and introduced into practice by Robert Koch as having bactericidal property. The disinfecting strength of steam is like that of boiling water. Vegetative forms are destroyed instantly by steam at a temperature of 100° C. (212° F.) and the spores of anthrax in about 5 minutes. The spores of some bacteria that occur in the soil (peptonizing milk bacteria (Flueffe) and the so-called potato bacillus (Globig)) are more resistant and are not destroyed until after an action of 10 minutes or more.

The action of steam is materially lessened by the admixture of air, which can absorb only small quantities of water and is a poor heat conductor. Thus steam at 100° C. with 8/10 saturation disinfects five times as slowly and with 7/10 saturation 22 times as slowly as if fully saturated. It is therefore necessary that with steam sterilization the air be expelled as completely as possible so that the infectious substance will be in saturated, so-called "streaming" steam. The name "streaming" steam should coincidentally indicate that the disinfecting apparatus is not only filled with steam at 100/ C. but is streaming with it during the entire time of disinfection in order always to be positive that the steam is saturated and possesses a temperature of 100° C.

The destruction of microörganisms by steam no doubt depends upon a coagulation of the protoplasmic protein with a subsequent cleavage of the protein molecules.

Steam penetrates into the material that is being disinfected better than dry heat. It is of great practical use in the practice of sanitary disinfection. Certain disinfecting apparatuses are used especially for this purpose, which, however, need not be discussed here, since they have

a very limited use in veterinary medicine. The chief use of steam in veterinary medicine is for the disinfection of instruments and bandaging materials.

Metal instruments and all kinds of textile fabrics of wool, cotton, jute, etc., can be disinfected by steam without injury, but no leather or fur goods. For these the vacuum apparatus (formaldehyle-steam sterilization in a rarefied air space) is most suitable; in it rubber goods, velvet and silk articles, sponges, feathers, documents and books can be disinfected. Colors that are not fast will run and also are injured otherwise.

Steam under pressure disinfects more powerfully than streaming or live steam. According to Globig the extremely resistant spores of the potato bacillus (*Bacillus mesentericus ruber*) were destroyed by saturated steam under a pressure of:

1.0 atmosphere and a temperature of 100° C (212° F.) in 5½ to 6 hours.

1.1 atmosphere and a temperature of 102.7° C. (216.3° F.) in 5½ to 6 hours.

1.2 atmosphere and a temperature of 105.2° C. (221.4° F.) in 5½ to 6 hours.

1.4 atmosphere and a temperature of 109.7° C. (229.5 F.) in ¾ hour.

1.5 atmosphere and a temperature of 111.7° C. (233.1° F.) in ¾ hour.

1.6 atmosphere and a temperature of 113.7° C. (236.7° F.) in 25 minutes.

2.0 atmosphere and a temperature of 120.6° C. (249.1° F.) in 10 minutes.

3.0 atmosphere and a temperature of 133.9° C. (273° F.) instantly.

4.0 atmosphere and a temperature of 144.0° C. (291.2° F.) instantly.

On the other hand an overheated, nonsaturated stream, due to an admixture of air, will destroy the disease germs more slowly than saturated steam at only 100° C. Overheated steam more closely resembles hot dry air in its disinfecting properties.

b. Chemical Disinfectants (Antiseptics)

Chemical disinfectants are indispensable in the practice of disinfection.

Disinfectants will exert an inhibitory action on bacterial life, especially on propagation, even in the weakest concentration which still displays a harmful action toward bacteria. This degree of poisonous action is called "growth inhibitory toxic value" or "inhibitory value." If the concentration of an effective disinfectant is increased, the vegetative cells without spores are first destroyed within a given time—"slight toxic value;" with a greater concentration finally the really resistant spores—"great toxic value."

Naturally the "inhibitory value" of a disinfectant is not sufficient for

the disinfection that must be carried out for combating epizoötics. At least the "slight toxic value" is required for pathogenic bacteria that do not develop spores, and for the spore-bearing pathogenic bacteria the "great toxic value" is necessary.

Antiseptics are not only poisonous for bacteria but also for people and animals, and toward these even to a higher degree than toward bacteria. This relation of the poison toward the pathogenic bacteria on one side and the animal organism on the other is referred to as the "relative toxic value." The relative toxic value of carbolic acid is 6, which means that carbolic acid is six times as poisonous for the higher mammals as for bacteria (e. g., anthrax bacteria). The relative toxic value of collargol (argentium colloidale) is very small; according to personal investigations it is less than 1. It has become of great practical importance in the form of "ventrase" as an internal disinfectant, especially as an intestinal antiseptic for calf scour, etc. Mention should also be made of salvarsan as an internal disinfectant against the causative agents of syphilis, equinepectoral influenza, etc.

The action of disinfectants is affected by a series of factors, of which the following will be mentioned here:

1. Species and strain of bacteria.

2. Previous growth conditions and age of the culture. (Resistance of bacteria decreases with age.)

3. Form of development of the bacteria. (Spores are decidedly more resistant than vegetative cells.)

4. The number of bacteria to be destroyed.

5. Chemical and physical nature of the material to be disinfected. Protein injures the disinfecting action of bichlorid of mercury. Spore-free anthrax bacteria are killed with bichlorid in distilled water in a concentration of 1:500,000, in bouillon 1:40,000, in blood serum 1:2,000. In a dry but viable condition disease germs are more resistant than in a moist condition.

6. The aggregate condition of the disinfectant (gaseous, liquid or solid).

7. Degree of concentration of the antiseptic.

8. Solvent for the antiseptic. Usually disinfectants act best in watery solutions (carbolic acid). Oily solutions are far less effective or even ineffective.

9. Presence of salts. The influence differs according to the salts as well as according to the disinfectant. The harmful effect (precipitation) of protein upon bichloride is overcome by the addition of chlorids (sodium chlorid, etc.) to the bichlorid solution.

10. The temperature. In general the action of disinfectants is enhanced by higher temperatures, even when the temperature alone does not suffice to destroy the disease germs.

11. The time required by the antiseptic to act upon bacteria.

The requisites for an ideal disinfectant are:

1. Great efficiency in low concentration and at ordinary temperature.
2. Easily soluble in water.
3. Stability.
4. Slight toxicity.
5. No harmful action on the objects that are to be disinfected.
6. No unpleasant and clinging odor.
7. Cheapness.

There is no disinfectant as yet that meets all of these requirements. One must in most cases endure certain disadvantages.

Among the strongest disinfectants are:

Strong mineral acids, such as sulphuric acid, hydrochloric acid, nitric acid and hydrofluoric acid.

The strongest oxidizing agents are ozone, chlorin (chlorin water), bromin (bromin water), iodin trichlorid, hypochlorous acid and its salts (chlorid of lime, antiformin), permanganate of potash with hydrochloric acid, hydrogen peroxid.

The salts of silver (silver nitrate) and of mercury (sublimate, sublamin, mercurial oxycyanate), also phenol sulphuric acid compounds and formaldehyde.

To the weaker disinfectants belong phenol, phenol derivatives, alcohols. and under certain conditions the soaps.

A mixture of several disinfectants usually is stronger than one alone.

In the following only a few antiseptics are chosen which are used in disinfection that must be carried out when combating diseases.[12]

1. Acids. For disinfection in general only sulphurous acid, sulphuric acid and hydrochloric acid are to be considered.

The disinfecting action of sulphuric acid is decidedly less than was formerly supposed. Even with 10 volumes per cent of air added the sulphuric acid fails to destroy spore-free bacteria even within 48 hours. Sulphuric acid is no longer used as a disinfectant against bacteria. On the other hand the sulphurous anhydrid (sulphur dioxid) has become of great practical importance in destroying animal parasites, mange mites, lice, etc., and is used a great deal in the treatment (gas chambers) and disinfection of blankets, cleaning implements, harness, etc., in mange cases.

Sulphuric acid is used in a 2 to 4 per cent solution in rough disinfection, and for this purpose the cheap, raw sulphuric acid is used, which acts as a splendid disinfectant for useless objects (dung, liquid manure, waste waters, etc.). Enough disinfectant is added with frequent stirring until the mass to be disinfected gives a decided and permanent acid reaction. Metal objects are affected by sulphuric acid.

Raw hydrochloric acid is also used for disinfection on a large scale and in like manner as the raw sulphuric acid just mentioned.

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[12]See also Farmers' Bulletin 926, U. S. Department of Agriculture, "Some Common Disinfectants."—J. R. M.

In comparison with the acids the lyes (hydroxids of the alkaline metals) possess but very little effect upon bacteria. The "inhibitory value" of soda lye is 1:2,270; that of ammonia is 1:417. Destruction of anthrax bacilli is accomplished with 1.4 per cent caustic potash solution in 10 minutes; with 1.0 per cent caustic soda solution in 10 minutes. On the other hand even a 10 per cent solution of caustic soda does not destroy tubercle bacilli in sputum in 24 hours; and spores of anthrax were still viable after 8 hours in a 4 per cent solution of caustic soda or a 5 per cent caustic potash solution.

Soda in a 16 per cent solution destroys spore-free bacteria (excepting tubercle bacilli) in one minute, while the destruction is uncertain in a 2 per cent solution at 50°C. (122°F.).

There is a great difference with soap (potash soap), since soaps of saturated fatty acids (palmitic and stearic acids) are more efficacious and destroy bacteria in a 0.72 per cent solution in 5 minutes. On the other hand potash soaps of unsaturated fatty acids (oleic acid and linoleic acid used in the production of official potash soap), also the resin soaps, are less effective. Thus a 3 per cent soft-soap solution at 50° C. (122° F.) exerts no positive destructive action on bacteria.

2. Lime is used a great deal for disinfection in the form of freshly slaked lime or as thick and thin milk of lime. For the preparation of slacked lime and the thick and thin milk of lime, see page 404.

Milk of lime serves for disinfecting walls and manure. Thick milk of lime put on in three coats at intervals of 2 hours will destroy the germs of swine erysipelas, swine hemorrhagic septicemia and hog cholera, glanders, fowl cholera and anthrax (vegetative cells) as well as pus cocci, but not tubercle bacilli and anthrax spores.

Milk of chlorid of lime (1.3) destroys anthrax spores in about one minute. A chlorid of lime suspension 1:100 destroys the bacteria of swine erysipelas, swine plague and spore-free anthrax bacteria in one minute. The tubercle bacilli in the expectoration from the lungs are also substantially more resistant against chlorid of lime.

Chlorid of lime consists chiefly of HO-Ca-OCl and Cl-C-OCl. In commercial chlorid of lime there is also present calcium chlorid ($CaCl_2$) and caustic lime (CaO). The German pharmacopeia prescribes a 24 per cent chlorid content; often the content is much less, and even with a strong chlorid odor the preparation may contain only a small percentage of active chlorid.

The milk of chlorid of lime lacks the solvent action of the milk of lime. The penetrating action of chlorid of lime is slight; as a result a thorough, mechanical cleansing during the disinfection with chlorid of lime can not be dispensed with.

Chlorid of lime is injurious to leather goods, blankets, cloths, etc. Caution is therefore recommended. Places disinfected with chlorid of lime retain the odor of the chlorid for a long time. This odor is easily

absorbed by milk. Even the meat of animals that have been stabled in such places (stables, cattle cars) is said to absorb such a strong chlorid odor that it is offensive and unpalatable (Dammann). Concerning the preparation of milk of chlorid of lime, see page 404.

Antiformin is closely related to chlorid of lime. It contains a 10 per cent solution of sodium hypochlorite and a 5 to 10 per cent solution of sodium hydroxid. It is a good bactericide but its high price is against its use as a disinfecting agent.

The neutral salts do not act bactericidally; even in stronger concentrations under favorable circumstances they only act inhibitorily upon bacterial growth.

The "inhibitory value" of sodium chlorid is 1:12.5; of dibasic sodium phosphate 1:5; of calcium chlorid 1:50; of lithium chlorid 1:1500.

Saltpeter (KNO_3) does not even inhibit in a 15 per cent solution.

Cuprum bichloratum is the most efficacious of the copper salts. It destroys staphylcocci in 5 hours in a 2.5 per cent solution. On the other hand it is practically ineffective against spores.

Of the iron salts ferric sulphate in a 2.5 per cent solution destroys typhoid baccilli in one minute. It is effective against spores, as are also lead nitrate, lead acetate, the chlorids of cobalt; cadmium, barium and zinc, and zinc and chromic sulphate.

Iron sulphate destroys the eggs of the intestinal worms even in a 1 per cent solution and is recommended for this purpose in disinfecting pastures.

3. Bichlorid of mercury is used as a disinfectant in a solution of 1:1,000. It is most easily prepared by a dissolution of "Angerer's pastilles" or tablets. Inasmuch as bichlorid of mercury forms insoluble compounds with protein, it can be used for the disinfection of fresh excretions rich in protein (blood, etc.) only if it contains sodium chlorid. The sodium chlorid prevents the precipitation of the bichlorid of mercury but simultaneously lowers its disinfecting effect. The Angerer pastilles contain equal parts of bichlorid of mercury and sodium chlorid, and in order to avoid mistakes the pastilles are mixed with eosin. The Angerer pastilles are usually used in a 1 to 2 per cent solution. In these concentrations a harmful action of the sodium chlorid upon the disinfection is hardly possible, but the precipitating action of bichlorid of mercury on the protein is sufficiently decreased by the sodium chlorid.

Soda and soap residue likely to remain from the preceding cleansing must be thoroughly rinsed off with water before the disinfection with bichlorid of mercury takes place. Twenty-four hours after disinfection of a cattle barn with bichlorid of mercury the barn should be rinsed with a 0.5 per cent solution of potassium sulphid in order definitely to prevent poisoning.

The poisonous quality of the bichlorid of mercury solution restricts its use considerably and permits its application only under supervision.

The public can not obtain bichlorid of mercury solutions (in Germany) without restrictions because the absence of odor and color can easily lead to accidental poisoning. Bichlorid of mercury is recognized as one of the most efficacious disinfectants.

4. Crude cresol which is chiefly a mixture of cresols (methylphenols), carbolic acid, higher phenols, hydrocarbons and acids, produces a fluid when mixed with the same volume of raw sulphuric acid while being cooled, that can be mixed with water without disintegration. This fluid is known as cresol sulphuric acid solution and is used with good results in a 3 per cent solution for disinfection on a large scale. Metals are affected by cresol sulphuric acid. A 3 per cent solution of a mixture prepared from 2 volumes of crude cresol and 1 volume crude sulphuric acid destroys staphylococci in 2 to 3 minutes.

Cresol sulphuric acid should not be used sooner than 24 hours after its preparation, nor later than 3 months. During the colder time of the year rock salt 0.5 kilogram (1 pound), according to the need, is added to 10 liters (11 quarts) of cresol sulphuric acid solution to prevent it from freezing. It should be carefully dissolved and mixed. If the material to be disinfected has previously been washed with soap or soda solutions it must be thoroughly rinsed with water before applying the cresol sulphuric acid.

Beside cresol sulphuric acid many other phenol and cresol preparations are used in the practice of disinfection. Only the most important are briefly mentioned here.

(*a*) Carbolic acid. It was introduced into medicine by Lister in 1867 for combating the diseases resulting from wound infections. A 1 per cent solution of carbolic acid kills staphylococci in 60 minutes, and a 5 per cent solution quickly destroys the spore-free bacteria excepting the tubercle bacillus in sputum. Carbolated oil and carbolated lime do not act bactericidally. After disinfection with carbolic acid, the carbolic odor clings to the place (thus requiring caution in stabling milk and slaughter animals), and the same is true of the other disinfectants of this group, having strong odors. Pure carbolic acid is used in a 3 per cent solution for disinfection, but it is expensive, and that is also true of most other disinfectants mentioned here.

(*b*) Creolin contains 66 per cent of indifferent aromatic hydrocarbons and 27.4 per cent cresols and higher homologs that are held in emulsion by resin soap. Desinfectol, cresolin, izal and sapocarbol are similar combinations.

(*c*) Liquor cresoli saponatus (cresol soap solution or saponified cresol solution)[13] consists of 1 part potash soap and 1 part of cresol carefully and uniformly mixed in a warm room. An aqueous solution

[13]Another cresol preparation, known as liquor cresolis compositus (compound solution of cresol), recognized by the United States Pharmacopœia, is composed of equal parts of cresol (U. S. P.) and linseed-oil-potash soap. It is an efficient disinfectant in a 3½ to 4 per cent solution and has the advantage of mixing readily with water.—J. R. M.

is used as diluted cresol water for disinfection on a large scale. For its preparation see page —.

(*d*) Lysol contains 1 part tricresol and 1 part linseed oil potash soap. The action corresponds to the cresol soap solution. But lysol is decidedly more expensive.

(*e*) Bazillol consists of similar ingredients as lysol but is weaker in action. A 1 per cent solution corresponds in disinfecting effect to about a 1 per cent solution of carbolic acid. Sapocresol, cresol Roschig, betalysol, carbosapol, bavarol, basol, etc., belong to this group.

(*f*) Aseptol is an orthophenol sulphuric acid. Sanatol is identical with Automors, shows a similar construction as aseptol but is judged adversely.

(*g*) Hygienol consists of cresols mixed with a 10 per cent solution of sulphuric acid.

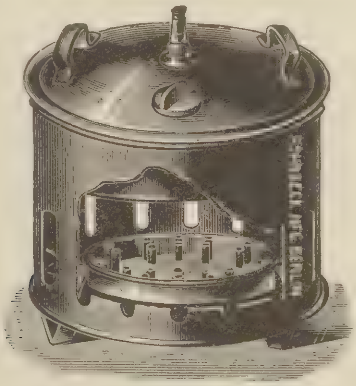

Fig. 266. Breslau apparatus.

(*h*) Phenostal, cresol oxalic acid and cresosteril are mixtures of phenol and oxalic acid. Phenostal is 2 to 6 times as active as carbolic acid but also much more poisonous. The carbolic acid tablets of Gentsch consist of phenol and phenol potassium. Metakalin is meta-cresol potassium; solutol is cresol sodium; solveol, sodium salt of cresolic acid or salts of oxycarbon and oxy-sulpho-acids; kresin is cresoxyl-acetic-sodium, and saprol contains 50 to 60 per cent of crude carbolic acid and 20 per cent mineral oil. A layer of saprol on the contents of a cesspool does not kill typhoid bacilli, but mixing it does; a 1 per cent solution kills in 5 days, 2 per cent in 6 hours.[14]

Formaldehyde (CH_2O), which during the past few years has been used extensively, deserves special mention. It is not only distinguished by a particularly bactericidal action even in weak concentrations, but furthermore offers the advantage of being usable not only in aqueous solutions (see page 405) but also in the form of a vapor for the disin-

[14] A list of proprietary disinfectants which are permitted for official disinfection may be obtained from the Bureau of Animal Industry, U. S. Department of Agriculture, Washington, D. C.—J. R. M.

fection of stables, dwellings, blankets, etc. But it must be mentioned that gaseous formalin acts only upon the surface of objects, therefore does not exert any action into the depths, and for that reason it is essential that a mechanical cleansing precede the formaldehyde disinfection.

Formaldehyde is an acrid, pungent gas that severely irritates the mucous membranes. Its 35 to 40 per cent solution in water, formalin or formol, formaldehydum solutum, should be kept tightly sealed and stored in the dark when not in use.

The inhibitory value of formaldehyde toward staphylococci is 1:5,000; anthrax bacilli, 1:15,000; colon bacilli, 1:100,000. It destroys staphylococci in 3 per cent solution (=7.5 per cent formalin) in 60 minutes; in 6 per cent solution, in 35 minutes. On the other hand anthrax spores are destroyed by 0.5 per cent formaldehyde in 14 to 21 hours; by 1.0 per cent in 12 to 19½ hours; by 2.0 per cent in 10½ to 17½ hours; by 3.0 per cent in 8¼ to 15½ hours; by 6.0 per cent in 6 to 13½ hours.

Paraformaldehyde, a polymerization product of formaldehyde, is a solid substance and is put on the market in tablet form. It acts only if combined with water. The polymerization of formalin to paraformaldehyde also takes place by the evaporation of formalin solution. To prevent this, various additions are made in the different procedures of formalin disinfection. Trillat adds 4 to 5 per cent calcium chlorid, for positive disinfection for each cubic meter of space 5 cubic centimeters of this "formochlorol solution" must be evaporated under a pressure of 3 atmospheres and allowed to act for about 20 hours. Walter and Schloszmann add 10 per cent glycerin to the formalin. The Lingner disinfection apparatus, which is necessary for this procedure, consists of a central boiler which contains the "glycoformol" and an outer double boiler for the water that is to evaporate. The water vapors enter into the boiler through a tube and spray the glycoformol from four fine nozzles in the form of a fine spray into the room that is to be disinfected. For a space up to 80 cubic meters an apparatus with 2 liters of glycoformol 1½ liters of hot water and ½ liter of 85 per cent denatured alcohol for fuel suffice. The disinfection is over after about 7 hours.

The Breslau disinfection apparatus mentioned by Fluegge[15] (Fig. 266) consists of a simple boiler of sheet copper with a lid soldered on tightly. The later is provided with a nozzle 0.6 centimeter wide, two handles and an aperture for pouring in, which can be closed tightly. The boiler

[15]For a disinfection that is to be in effect for 7 hours the Breslau apparatus constructed by Fluegge is charged with—

Space, cubic meters	Formalin, cc.'s (40 per cent)	Water, cc.'s	Alcohol, cc.'s (86 per cent)	Space, cubic meters	Formalin, cc.'s (40 per cent)	Water, cc.'s	Alcohol, cc.'s (86 per cent)
10	200	800	200	90	700	2,800	850
20	250	1,000	250	100	750	3,000	950
30	300	1,200	300	110	800	3,200	1,050
40	400	1,600	400	120	900	3,600	1,150
50	450	1,800	500	130	950	3,800	1,200
60	500	2,000	600	140	1,000	4,000	1,300
70	550	2,200	650	150	1,050	4,200	1,400
80	650	2,600	750				

With spaces of more than 150 cubic meters 2 apparatuses should be used.

rests on a frame under which there is an alcohol lamp for heating purposes, constructed after the rapid cooker type. To avoid polymerization the formaldehyde is converted into an 8 per cent aqueous solution. For 1 cubic meter of space and for a disinfection lasting 7 hours about 2.5 grams of pure formaldehyde are necessary, and for 3½ hours' action 5 grams formaldehyde are necessary.

Other forms of formalin disinfection apparatus are described in literature. The spray and evaporation methods are almost equally satisfactory. The space to be disinfected should be heated to 20 to 25°C. A formalin disinfection without special apparatus has also been attempted according to Springfield by means of glowing hot chains,

Fig. 276. Disinfection of a stable with Autan.

Dieudonné, with hot stones, which they brought in contact with formalin and thus evaporated the formaldehyde. Confirmation of these methods have in the past been published but sparingly.

Formalin disinfection as it was formerly attempted with the help of a simple lamp apparatus which oxidized the methylalcohol by partial combustion to formalin has been given up as useless. Schering's small apparatus in which paraformaldehyde pastilles were evaporated in a small kettle by means of an alcohol lamp also produced insufficient disinfecting action, since with it, as with the lamp apparatuses, the space to be disinfected is not saturated with steam, which is necessary in order to obtain proper results (Fluegge).

In conducting formaldehyde disinfection the following points must be observed:

Living animals and plants, manure, litter and remains of food should be removed from the place that is to be disinfected. The latter should be swept scrupulously clean and heated to 15 to 20° C. (59 to 68° F.). Blankets, clothes, etc., that are also to be disinfected should be hung up so that they hang free, pockets turned inside out and the doors of cupboards, closets, etc., opened. Then the doors and windows of the room are carefully sealed and the keyholes stopped up. The ventilating apertures and stove doors are likewise tightly sealed or pasted shut.

The apparatus is then filled and set up in such a way that a space of at least half a meter (yard) is left free all around it; the alcohol is lighted, and the disinfectors leave the room and seal the door from the outside. After the disinfection has been completed the formalin should be removed by airing or should be fixed with ammonia vapors (hexamethylentetramin $(Ch_2)_6N_4$ is formed). The latter is generated by the evaporation of a 25 per cent solution of ammonia, the amount of which should be in proportion to the formalin that has developed. The vapors are conducted into the room through the keyhole.

To dispense with the more or less expensive formalin disinfecting apparatus a series of procedures without apparatus have been attempted, of which many have not been approved. The better procedures without apparatus are:

1. Autan procedure. Autan consists of 71 parts of barium superoxid and 20 parts paraform (by adding water it generates heat and the water and formaldehyde evaporate with a partial oxidation of the formaldehyde. Autan is put on the market by Bayer & Co., Elberfeld, Germany. Since the disinfecting power was insufficient at first, the amount of paraform was later increased (packing B), and was packed separately from the barium superoxid to avoid oxidation. In this form the autan proved satisfactory for disinfection and was officially declared admissible into the practice of disinfection in Germany in 1908. As shown in Fig. 267, the autan is mixed with water in a sufficiently large wooden vessel. The room should be well sealed. The formalin vapors should be allowed to act for 5 to 7 hours.

2. Potassium permanganate. Formerly an aqueous solution of formaldehyde was allowed to act upon potassium permanganate crystals. Later the solution was replaced by a solid aldehyde (formangan). With the action of the formaldehyde upon the potassium permanganate, using solid formaldehyde with the addition of water, heat is generated and evaporation of water and formaldehyde takes place. Ten grams of paraform with 25 to 30 grams of water or 25 grams of 40 per cent formaldehyde solution and 25 grams of potassium permanganate are necessary for 1 cubic meter of space.

3. Aldogen procedure. With this method paraformaldehyde is allowed to act upon chlorid of lime with the addition of water.

Methods for testing the disinfecting action can not be discussed here. Reference should be made to the appropriate literature.

The use of gaseous substances other than formaldehyde has not been satisfactory for disinfecting rooms. Oxygen only harms the anaerobes and hydrogen the strict aerobes. Nitrous oxid, oxid of nitrogen, nitrogen dioxid, carbon monoxid, carbonic acid, hydrogen sulphid and sulphurous acid do not act sufficiently bactericidal. Even chlorid and bromid vapors are not to be used (as they affect objects severely).

The choice of disinfectant depends upon the resistance of the bacteria. Milk of lime, lye and thin milk of chlorid of lime are sufficiently strong for swine erysipelas and swine plague bacilli. The intensive disinfectants such as carbolic acid, cresol preparations, sulphocarbolic acid, bichlorid solution and milk of chlorid of lime must be used for the tubercle bacillus and especially for the anthrax organism (spores).

Disinfection should be carried out with great circumspection and expert knowledge, and scattered pathogenic germs should be destroyed wherever they can be reached. Therefore the disinfection of a stable should not be restricted to the stable room but should include the stable appliances, grooming utensils, blankets, harness, manure, shoes and clothes of attendants, the feet of the animals, etc.[16]

In the practical application of disinfection mechanical cleaning should precede the disinfection. The rooms, etc., should be swept thoroughly, the filth scraped or scrubbed from the floor, cribs, racks and walls, the ceiling and walls should be brushed off, and wooden objects should be planed off, etc. This procedure removes many bacteria besides aiding and making possible real disinfection which follows. Objects of little or no value should be burned or buried at once. Destruction, i.e., disinfection, must take place whenever the mechanical removal of disease germs is impossible.

If the rooms can be sealed tightly, use is often made of the disinfection with evaporated formaldehyde. In stables and cattle cars this preliminary condition for formalin disinfection often does not exist. Use must then be made of other methods of disinfecting. Disinfecting sprayers are used for scattering liquid disinfectants. The best ones are those that are portable and can be handled and worked with one hand so that the hose can be guided with the other hand. The nozzles must be well made, be easily cleaned and permit a thick suspension (white-wash) to be sent in an unbroken stream over a fairly large area. The container should be made of leaded tin. Most outfits are similar to those used in orchards and vineyards.

The disinfection of sheep barns offers special difficulties. With regard to reportable diseases in Germany the imperial animal disease law must

[16]See also Farmers' Bulletin 954, U. S. Department of Agriculture, "The Disinfection of Stables."—J. R. M.

be observed. The disinfection of stables should not be neglected even with diseases that need not be reported (sheep glanders, abortion, inflammation of the udder, diplococcic and streptococcic diseases, dysentery, polyarthritis of lambs, diphtheria, vaginal and uterine gangrene, bradsot, infectious panaritium, worm diseases, etc.). Many difficulties would be met in proceeding with the disinfection in these cases according to the instructions of the German laws, i.e., first of all to remove all the manure lying in the sheep barn. This may often be omitted, however, since the thick layer of manure lying in the stable offers favorable living conditions to the bacteria only in its upper layer of 10 to 20 centimeters in thickness. A higher temperature (about 50° C.) exists in the lower layers, which either weakens or destroys the germs. The removal of the manure is therefore usually limited to the upper 10 to 20 centimeters which is stacked on a large heap outside of the barn, covered and disinfected by self-heating. The manure left in the barn is covered with a layer (5 centimeters thick) of sand or peat, which is disinfected with milk of lime, lysol, bacillol or the like, and then given a new layer of bedding, which should be sprinkled with a watering can once daily for eight days with limewash or lysol water. Racks and other stable implements should be scrubbed with hot soda solution and then whitewashed. Clothes and shoes of the attendants should be cleaned in the customary way and then disinfected. The nature of the disease will decide the importance of disinfecting the feet of the sheep.

The official German instructions for compulsory disinfection are as follows:

German Official Instructions for Disinfection

I. General Considerations

I. The cleaning and disinfection according to the regulations are done under the supervision of contingent regulations of the official veterinarian and under police inspection.

II. The disinfection procedure includes cleaning and disinfection. Disinfection must always be preceded by cleaning, even though a preliminary disinfection has been carried out at the beginning of the process of cleaning.

II. Cleaning

Method of Procedure.

III. After a preliminary disinfection (Section V, No. 10, Paragraph 2) persons must necessarily wash with soap and warm water their hands and any other parts of the body that have become soiled and must free the clothes as well as the shoes of dirt that has stuck fast. This is best done by brushing with soapy water if the clothes and shoes are not changed.

IV. The bodies of the animals, including hoofs, must be carefully cleaned of all dirt by washing or some other suitable method. If necessary the hoofs should be pared out.

V. Stables and other shelters should be treated as follows:

1. Manure and other coarse dirt, bedding, remains of feed, straw pads and the like should be removed and dealt with according to No. 9, 10. The removal of the manure in sheep and cattle barns can be left to the judgment of the official veterinarian as far as the upper layer is concerned.

2. Wooden implements, wooden racks and cribs as well as board casings should be removed if necessary. Woodwork whose upper surface is worn rough and ragged must be planed down sufficiently to be smooth again.

3. A layer of suitable thickness must also be removed from clay walls. Defective places in the plaster on the walls should be removed and treated in similar manner as the manure.

4. Paving and wooden floors that are not impervious should be taken up. All material underneath that has been soaked by excreta should be dug out and treated as is the manure. Stones and sound woodwork into which no moisture has penetrated may be used again after defective parts have been removed and after a thorough cleansing.

5. With impervious paving it is necessary to scrape out or to remove all defective places in the cement or in the material itself, or cracks in the material, and after cleaning and disinfection to refit these or replace them with new material. The same method of procedure should be carried out with suitable material on the walls, pillars and stall partitions, in pits and troughs, gutters and sewers.

6. With dirt floors (loam, clay and the like) the upper layer should be removed. Damp places should be dug out. The parts that have been removed should be treated as is manure.

7. Dirt and sand floors should be dug out as far down as the excreta have soaked in, at least 10 cubic centimeters. The parts dug out should be treated as is manure.

8. Ceilings and walls, articles of equipment (feed boxes, mangers, trough racks, posts, pillars, stall partitions, doors, door posts, windows, etc.), also the floor, the liquid manure gutter, sewers and pits, should be cleaned by thorough scrubbing with hot soda solution (solution of at least 3 kilograms of washing soda in 100 liters of hot water, or 6 pounds to 25 gallons) or with a hot soap solution (solution of at least 3 kilograms of soft soap in 100 liters of hot water). The cleaning should be considered complete only when all matter discharged by sick or suspected animals and all dirt from the substratum have been removed and all gives a very clean impression. If necessary cleaning sand can be used with the hot soda or soap solution. The cleaning must include all parts of the stable or other shelter. It should be conducted with special attention to depressions in the floor, stable corners, grooves, cracks, etc. In stables and other shelters the cleaning should as a rule begin at the ceiling, then the walls and inside equipment, and last of all the floor, urine gutter, etc.

If the official veterinarian deems it satisfactory, scrubbing the stable ceilings and high parts of the walls that have not been soiled by the excreta of sick animals with soda or soap solution may be omitted and the cleaning merely done by thoroughly spraying with a hot soda or soap solution or with hot water. Where hot soda or soap solutions or hot water can not be obtained in sufficient quantity, then according to the judgment of the official veterinarian a stream of cold water may be used under strong pressure from a hand fire hose, garden hose or similar device.

9. The manure and other parts that have been removed during the process of cleaning, blood, stomach and intestinal contents, other refuse of slaughtered, diseased or suspected animals should be collected on the farm where the outbreak has existed. In case it is impossible or unsuitable to collect the manure on the farm premises, it may with consent of the official veterinarian, be transported to a suitable place outside of the farm if the required precautionary measures are observed.

The dirty water that results from the cleaning should be collected in the urinal pit or in some other container on the farm premises.

10. If the manure and other dirt that is to be removed during the cleaning, the bedding, feed remnants, etc., and the fluids resulting from the cleaning can not be collected on the farm or at some other place outside of the farm premises without danger of spreading the disease, then a disinfection, preliminary to the cleaning, must take place in so far as it is necessary, by pouring suitable disinfectants over all the materials that are to be removed. In such a case care should be exercised that the manure and other filth, bedding, feed remnants, dirty water, etc., are not temporarily carried, before the disinfection has been accomplished, to places from which the dirty water can flow to other farms, on roads used by other people and animals, or into wells, drains and other waters that are used.

Preliminary disinfection must also take place before the cleaning if without previous disinfection there would be danger of infection for the persons engaged in the cleaning, as would be the case with anthrax and glanders.

VI. (1) Implements, wearing apparel and other articles are to be treated in the following manner:

1. Articles of slight value that can be burned should be burned.

2. Wooden stable and carriage or wagon appliances (feed boxes, pails, broom handles, fork and shovel handles, etc., winnowing fans, wagons, sledges, parts of harness, wooden shoes, etc.) should be scrubbed thoroughly with hot soda or soap solution.

3. Implements made of iron or other metal (chains, rings, forks, shovels, curry combs, bridle bits, muzzles, troughs, other feeding and drinking vessels and other vessels, cages, etc.) are to be cleaned thoroughly and rinsed off with hot water whenever they can not be subjected to disinfection by fire.

4. Leather or rubber parts (halter, bridle belt, harness saddle, straps, covers for pads, leather shoes, dog collars, muzzles, whips, etc.) should be scrubbed off with soapy water.

5. Articles of cloth (blankets, girths, halter, ropes, covers for pads, wearing apparel, bedding, etc.) should be freed of dirt by brushing with soapy water.

6. Hair, wool, feathers, cushion padding and similar articles should be laid out in thin layers, be aired at least for 3 days and turned often.

(2) In such cases as in Section V, No. 10, paragraph 2, a preliminary disinfection of utensils, wearing apparel and other articles is also necessary.

VII. The provisions of Sections V and VI are applicable to the cleaning of loading platforms and similar stations, including slaughtering places, also ship quarters and ferry boats.

VIII. Cattle market places must be cleaned so that the feces discharged by the animals are collected. Paved cattle market places should be thoroughly cleaned with a broom or rinsed off with water. Cattle market places that are not paved should be leveled with hoes or harrows. In case of necessity tying devices should also be rinsed off or washed off with water.

IX. Roads (streets) should be cleaned in the same manner as the market places, according to their structure.

X. Inclosures on pastures (exercising lots, runs, milking places and the like) should be cleaned in the same manner as the market places according to their structure.

III. Disinfection

1. The Disinfectants

XI. Disinfectants to be used are:

1. Freshly slaked lime. It is prepared as follows: Fresh quicklime is placed in large lumps in a large vessel and evenly sprinkled with water (about half the quantity of lime). It distintegrates into a powder with the generation of heat and bubbling.

2. Milk of lime. It is used as thick and thin milk of lime. Thick milk of lime is prepared by gradually adding while constantly stirring 3 liters of water to every 1 liter of freshly slaked lime.

Thin milk of lime is prepared by gradually adding while constantly stirring 20 liters of water to every 1 liter of freshly slaked lime.

If freshly slaked lime is not available the milk of lime may be prepared by stirring together 1 liter of slaked lime, as it occurs in a lime pit, with 3 or 20 liters of water. Care should be exercised, however, that in this case the upper layer of lime which is changed by atmospheric influences is removed from the pit. The milk of lime should be shaken or stirred before using.

3. Milk of chlorid of lime. This is prepared from chlorid of lime (calcaria chlorata of the German Pharmacopeia) which has been stored in tightly sealed containers protected from the light and which must possess a pungent chlorid odor, as follows: To every 1 liter of chlorid of lime gradually add while constantly stirring 3 or 20 liters of water (thick and thin milk of chlorid of lime). Milk of chlorid of lime must always be prepared freshly before use.

4. Diluted cresol water (2.5 per cent[17]) For this preparation add to 50 cubic centimeters of cresol soap solution (liquor cresoli saponatus of the German Pharmacopeia) enough water to make 1 liter of disinfectant fluid and mix thoroughly.

5. Carbolic acid solution (about 3 per cent). To prepare add to 30 cubic centimeters of liquid carbolic acid (acidum carbolicum liquefactum of the German Pharmacopeia) enough water to make 1 liter of disinfectant fluid and mix thoroughly.

6. Cresol sulphuric acid solution (3 per cent). To prepare first add 2 volumes of crude cresol (cresolum crudum of the German Pharmacopeia) to 1 volume of crude sulphuric acid (acidum sulfuricum crudum of the German Pharmacopeia) at ordinary room temperature. After not less than 24 hours enough water is added to 30 cubic centimeters of this mixture to make 1 liter of disinfectant fluid and is mixed thoroughly. The cresol-sulphuric acid solution should be used within 30 months after its preparation.

If the cresol-sulphuric acid solution is used for disinfecting places out of doors (portions of a yard, loading places, etc.) sodium chlorid (0.5 to 1 kilogram to 10 liters of cresol-sulphuric acid solution) should be added (while carefully stirring) during cold weather to prevent ice from forming.

Stables, yards, appliances, etc., that have been cleaned with soda or soap solution should be rinsed with water to wash off all remaining soda or soap before the disinfection with cresol-sulphuric acid solution is begun.

7. Bichlorid of mercury solution (0.1 per cent). To prepare dissolve 1 gram each of bichlorid of mercury and sodium chlorid with the addition of a small amount of red dyestuff in 1 liter of water, or dissolve one of the pink sublimate pastilles that can be purchased (pastilli hydrargyri bichlorati of the German Pharmacopeia) with 1 gram bichlorid of mercury in 1 liter of water.

Stables, yards, appliances, etc., that were cleaned with soda or soap solution should be freed of remaining soda or soap by rinsing with water before the disinfecting with the bichlorid solution is begun.

The work of disinfection for which large quantities of bichlorid are used, as with the disinfection of stables, yards, etc., may be done only under veterinary or police supervision. It is advisable, especially with the disinfection of cattle barns, to rinse all articles treated with bichlorid with a 0.5 per cent solution of potassium sulphid (kalium sulfuratum of the German Pharmacopeia) 24 hours after the bichlorid disinfection.

8. Formaldehyde solution (about 1 per cent). To prepare add to 30 cubic centimeters of commercial formaldehyde solution (formalin) enough water to make 1 liter of disinfectant solution and mix thoroughly.

9. Steam in apparatus that has been treated not only at erection but also later at regular intervals by experienced persons and found suitable.

Furthermore, steam from a steam kettle can be used to steam the inside and outside of smaller vessels that are closed entirely excepting for one opening, as, for example, milk cans, if the steam streams out under pressure and is led directly from the opening out of which the steam pours into the vessels. The inside of the vessels is subjected to the streaming steam, and this must be followed by a careful steaming of the handles and gaskets and the outer wall, the latter especially in the case of wooden vessels.

10. To clean by boiling in water or in 3 per cent soda or soap solution (Section V, No. 8). The fluid must be put on cold, must entirely cover the articles and be kept boiling for at least 15 minutes after it has begun to boil. The vessels in which the boiling is done must be covered.

For milk pails and vessels for storing and transporting milk we can substitute for the preceding method of boiling the following:

(*a*) Placing the vessels into boiling hot water or boiling hot soda solution or thin milk of lime for at least 2 minutes so that all parts of the vessels are covered by the fluid.

(*b*) Thoroughly brushing the inner and outer surfaces of the vessels, also the handles, lids and other sealing devices, with boiling hot water or boiling hot soda solution or thin milk of lime.

[17] A 6 per cent cresol water is used for swine plague and hog cholera. For this preparation 120 cubic centimeters of cresol soap solution is used instead of 50 cubic centimeters as mentioned above.

11. Through singeing or heating in fire or in a suitable flame.
12. Burning.

(a) The disinfectants mentioned under Nos. 4 to 7 are to be used hot as much as possible.

(3) According to more recent regulations of the government other agents, tested with regard to their disinfecting qualities and practical usefulness, and other methods of procedure may be used.

2. Selection and Method of Application of Disinfectants

XII. The selection and method of application of the disinfectants (XI) must in general conform to the degree of resistance of the infectious substances of the disease as well as the ease with which they can be carried off by intermediate carriers and also to special conditions of the case.

XIII. In the case of cattle diseases, whose infectious substances are easily destroyed and in reality scattered but slightly by the diseased animals, the cleaning suffices if followed by whitewashing the stable ceiling, walls, posts, pillars, stall partitions, doors and floor, also the stall gutter and implements, with thin milk of lime or milk of chlorid of lime. Iron parts should be painted with diluted cresol water or with carbolic acid solution. The same method of procedure may be applied to wooden and stone parts as well as to glazed clay tiles in place of the whitewashing with milk of lime or milk of chlorid of lime.

XIV. (1) With diseases whose infectious substances are destroyed with difficulty or offer serious danger of spreading by means of intermediate hosts the following method of procedure should be followed:

1. Bedding materials, manure and other dirt, feed remnants and the like that were removed and collected during the cleaning process should either be burned, buried, ploughed under or be rendered harmless by packing or mixing with an appropriate disinfectant.

The packing of manure, bedding, feed remnants and similar substances should be done at a place that can not be entered upon by animals that are susceptible to the disease or by unauthorized persons, and from which the dirty water can not drain to other farms, on roads accessible to strange persons and animals or into wells, streams and other waters that are being used. It should be carried out in the following way: feces and bedding in the proportion of about 2:3 should be thoroughly mixed and slightly dampened, heaped lightly in large piles for three weeks. Dry manure should be soaked through with liquid manure or water (about 10 to 15 liters to 1 cubic meter of manure) after stacking. For the remainder proceed as follows: A layer 25 cubic meters thick of noninfected manure, straw or peat is spread out to a width of about 1.5 to 2 meters and of any length whatever, and upon this the manure to be disinfected is packed in a pile with sloping sides to a height of about 1.25 meters from the ground. The upper surface of the pile is covered with a layer about 10 cubic meters in thickness of nondisinfected dung, straw, leaves, peat or other loose material and then this is covered with a layer of earth 10 cubic meters in thickness. After having been packed for three weeks the manure can be removed without further danger.

The removal from the infected farm of manure and bedding material that has not been packed must be done in wagons as tightly sealed as possible and without the use of animals from other farms that would be susceptible to the disease. In case of necessity the manure, bedding materials, etc., can be sprinkled layer by layer with thick milk of lime before removal if the nature of the infectious matter does not require the use of a different disinfectant. In case the manner of storing the manure is associated with danger of carrying the infectious substance through dirty drainage water to other farms, on roads accessible to strange people and animals, to wells, water courses and other useful water, then the manure must be treated with thick milk of lime while in the barn before it is taken to the storage place.

2. Urine and filthy water should be disinfected with lime or thick milk of lime, or with chlorid of lime or thick milk of chlorid of lime, in so far as they are not used in the packing of manure (No. 1). At least 1 volume of lime or chlorid of lime or 3 volumes of thick milk of lime or thick milk of chlorid of lime should be used to 100 volumes of liquid manure or filthy water and should be stirred in thoroughly and allowed to stand for at least two hours.

3. Feed and straw supplies that were in the places that are to be disinfected should be harmlessly removed if no other orders exist for particular diseases.

4. The ceilings and walls, articles of equipment (cribs, troughs, mangers, racks, posts, pillars, partitions of stalls, doors, door posts, windows, etc.), also the floor, including gutters, sewers, pits and troughs, should be whitewashed with thin milk of lime or milk of chlorid of lime, or be painted or thoroughly sprayed with diluted cresol water, carbolic acid, formaldehyde, bichlorid, or cresol sulphuric acid solution.

Iron parts should be treated with diluted cresol water or with a carbolic acid solution.

5. Yard inclosures, loading places, slaughtering places, cattle market places, roads (streets), etc., also ship quarters and ferry boats, should be treated with thin milk of lime or milk of chlorid of lime, or with a different disinfectant, applied in a suitable way. During cold weather the treatment may be done with sulpho-carbolic acid containing sodium chlorid or by scattering powdered, freshly slaked lime.

The same method of procedure may be followed with yard inclosures, cattle market places, roads, streets and inclosures on meadows that have a pervious paving or no paving at all.

6. Earth or sand floors that have not become saturated with excreta from diseased or suspected animals, including the layers under the floors after the latter are dug out (Section V, No. 4, paragraph 7) and the layers of manure not removed during the cleaning process in sheep and cattle barns, should be covered uniformly with thick milk of lime or with freshly slaked lime.

7. Wooden implements or vehicles, including wagons and sledges, upon which carcasses and parts of carcasses, bedding, manure, stomach and intestinal contents of slaughtered or diseased animals have been hauled, should, in so far as it is not advisable to burn them, be singed or be painted with diluted cresol water or with carbolic acid solution, formaldehyde solution, cresol sulphuric acid solution or bichlorid solution.

8. Iron implements or other metal should be exposed to the action of fire for a short time or be painted with diluted cresol water, carbolic acid solution or formaldehyde solution.

9. Articles of leather (especially shoes) or rubber should be rubbed off carefully and repeatedly with cloths that have been soaked in cresol water, carbolic acid solution or bichlorid solution.

10. Linen, hemp (jute), cotton and woolen articles, clothes and bedding, hair, wool, feathers, feed bags, paddings and the like should, in so far as it is not advisable to burn them, or if nothing else has been ordered for particular diseases, be disinfected by being placed for 24 hours in diluted cresol water in a carbolic acid solution, bichlorid solution, formaldehyde solution or by boiling or with steam apparatus.

Clothes that have been but slightly soiled can be disinfected by dampening with diluted cresol water, carbolic acid solution, bichlorid solution or formaldehyde solution, and brushing while damp.

11. Animals should be washed off with permissible disinfectants, especially such places where the skin and hoofs were soiled by feces or other excreta.

12. Hands and other parts of the body of persons should be thoroughly scrubbed with diluted cresol water, carbolic acid solution or bichlorid solution and should then after about 5 minutes be washed with warm water and soap.

With regard to the special directions concerning the methods of procedure with individual diseases, refer to the particular provisional instructions.

The execution of the disinfection rests with the owners and their help, who often have little understanding of this work. The disinfection would be accomplished much more expediently, more thoroughly and generally more quickly if, as with human diseases, the disinfection were undertaken by trained disinfectors. The training of well-informed lay disinfectors is also a necessity for combating epizoötics.

3. Harmless Removal and Utilization of Carcasses and Parts

Many bacteria remain viable and infectious for a long time in the diseased carcass. These sources of infection should therefore be re-

moved quickly from the reach of susceptible animals and in such a way that all danger of infection is permanently abolished. An immediate, harmless, total removal of diseased, killed or sick animals or of those suspected of the disease is ordered by law (in Germany) with regard to anthrax, blackleg, bovine hemorrhagic septicemia, rabies, glanders and rinderpest. Furthermore the pathological parts of animals that have been killed because of having foot-and-mouth disease, or that have been suspected of having that disease, including the lower part of the feet with the skin as far up as the fetlock joint, the pharynx, stomach and intestinal tract is ordered; also the lungs of animals afflicted with contagious pleuropneumonia that have been slaughtered or that have died, the carcasses with the fleece of sheep that have succumbed to sheep pox, as well as the fleece of sick sheep that were slaughtered before the disease was completely cured, the carcasses of hogs that have died of swine plague, hog cholera, or swine erysipelas, of poultry that have died of fowl cholera or fowl pest. Legal provisions have also been made concerning the removal, destruction and utilization of the carcasses of animals that have died from other diseases.

The carcasses or parts of carcasses of animals that were affected with or were suspected of having diseases that must be reported are to be disposed of according to official (German "Instructions for the harmless removal of carcasses and parts of carcasses," under the supervision of possible orders of the official veterinarian and under police inspection,[18] in one of the following ways:

(a) Cooking or steaming until the soft parts fall apart.
(b) Dry distillation.
(c) Chemical treatment until soft parts dissolve.
(d) Cremation.

Burying shall be resorted to only when the methods just mentioned are not feasible. The burial of carcasses or parts of carcasses of animals affected with or suspected of having anthrax, blackleg or bovine hemorrhagic septicemia may be permitted by the official veterinarian only if according to his judgment burning or one of the other methods designated above for harmless removal is impossible.

a. Burial of Carcasses

Danger of spreading infectious substances may be incurred in the burial of carcasses and parts of carcasses, especially if certain precautionary measures are not adequately followed. This method should be used only when the previously mentioned methods of harmless removal are not feasible. This is especially true of carcasses and parts of carcasses of animals that have died of, or were suspected of having anthrax, blackleg or bovine hemorrhagic septicemia.

For the burial of carcasses or parts of carcasses whose harmless removal has been ordered by law (it is advisable to deal with others from a most practicable point of view), dry places at a sufficient distance from human dwellings, cattle barns, wells, pools or streams, pastures and public roads should be selected. Humous soil, loamy or peat ground, land abounding with springs, gravel or sand pits which are designated or

[18]The police inspection may be omitted when the knacker's yards and the establishments for the utilization of carcasses are under veterinary police supervision.

suited for utilization, as well as places where the ground water is at least 2 meters under the surface, should be avoided wherever local conditions make this possible.

The burial places should be inclosed so that horses, ruminants, hogs and dogs can not get at them. Allowing animals to pasture on burial places, the use of plants that grew there as feed or bedding, as well as the stacking of feed and bedding on such places, are forbidden. The pits required for the burial of carcasses or parts of carcasses are to be dug deep enough so that the upper surface of the carcasses or parts of carcasses are covered by a layer of soil at least 1 meter (yard) in depth from the edge of the pit.

The hides of carcasses whose skinning is forbidden should be cut several times before burial so as to make them useless. Deep gashes should be cut into the carcasses and lime or fine sand scattered over them, or tar, crude coal-tar oil (carbolic acid, cresol) or alpha-naphthylamin in a 5 per cent solution should be poured on, or they should be treated with some other substance approved by the official veterinarian.

After the carcasses have been placed in the pit the places on the ground or grass that have been soiled with blood or other discharges should be scraped off and be buried with the carcass.

Pits in which carcasses or parts of carcasses of animals that were stricken with or suspected of having an epizoötic disease may not be opened or used again except with the consent of the police authorities.

The causative agents of disease sometimes remain viable and infectious in the buried carcass for a long time. Thus Cadéac and Malet found tubercle bacilli in decomposed pieces of cattle lungs that had been buried in damp sand still infectious after 5 months. Schottelius obtained infectious material from buried cadavers of phthisis cases after 2 years (!). On the other hand Klein found that the tubercle bacilli in a buried guinea-pig had already died after 7 to 10 weeks. According to Loesener, carcasses of animals that were affected with swine erysipelas remain infectious for 8 months. According to personal researches the rabies virus can remain virulent in the brain during the colder time of year for 2 to 3 weeks. According to the investigations by Kleins and Esmarch, carcasses of animals that were affected with anthrax cease to be infectious after several days, presuming that no spores have developed. If, however, spores have developed, they have been found to be virulent after a year (Loesener).

Staphylococcus pyogenes aureus dies after 1 to 2 months; *Bacillus pyocyaneus* after 38 days (Loesener). The virus of rinderpest remains virulent according to Dammann for months and even for years!

Burial is not an ideal method of removal for carcasses of animals that were affected with anthrax or blackleg. Although it has been emphasized above that burial should be resorted to only when harmless removal by intense heat or by means of chemicals is impossible, it is still

frequently practiced in the country. According to various observations anthrax carcasses buried in this manner produce a source of infection for many years that can scarcely be removed and which often causes many deaths yearly. The failure to conquer anthrax within the last 10 years is traced by many reputable official veterinarians to this very practice of burying carcasses. The establishment of common burial places in knacker's [19] yards does not entirely eliminate the dangers, since the choice of places for knackers' yards is usually made according to economic conditions and not according to the soil conditions, and not the ground-water level, the location of springs and streams, etc.

How much danger of infection arises from the carcasses buried as required by law is a question that has not yet been settled. The possibility of earthworms, moles and rats carrying disease germs to the surface of the ground must not be overlooked even though many facts point against such transportation. According to the tests of Naegeli, Renk, Pfeiffer, Petri and others, even strong air currents can not drive germs through a dry layer of soil of only a few centimeters thickness. Much less can this be done by the slowly moving air currents in a damp layer of earth of considerable thickness. The ground-water that rises through capillary action also can not essentially raise disease germs (4 to 5 cubic meters—Pfeiffer; 10 cubic meters—De Blasi). A washing downward by the descending movement of the soil moisture to the ground-water is likewise impossible in compact soil, for at one time such soil possesses an unusually great power to keep back bacteria (surface attraction—Fodor, Graucher and Deschamps) while at another time the downward movement takes place very slowly, so that months, often years, pass before the ground water is reached (Hofmann). Finally, disease germs that have reached greater depths (below 2 meters—which would be possible only in soil containing coarse gravel or boulders, as well as in cleft rock) would generally not be able to proliferate there because the temperature is too low. Thus C. Frankel observed that anthrax bacilli in culture tubes did not continue growing when sunk to a depth of 3 meters.

The burial of diseased carcasses will, however, easily lead to the spread of disease germs if it is not conducted entirely as ordered by law. Autopsy often takes place before the interment, and always causes the ground to be soiled with blood, excrement, etc., thus causing a scattering of disease germs. If the soiled earth is not carefully collected and buried with the carcass or disinfected, the way is clear for further spreading of the disease. If the carcasses are not buried deeply enough communication with the surface of the ground is favored.

b. Cremation

Burning animal carcasses is certainly to be preferred to burial, and

[19] A knacker is a dealer in dead and decrepit animals.

should be done when an adequate utilization is impossible, especially with anthrax, blackleg and swine erysipelas.

The simple, exposed cremation upon an open field often fails to bring about the desired results and frequently does not result in the complete charring of the cadaver, in spite of the consumption of much time and fuel. This is perhaps the chief reason why in years gone by so little use was made of this method. Far better results are obtained if the cremation is done in the following manner:

A pit with steep sides is dug as near the carcass as possible, for large animals 0.75 meter (30 inches) deep and 2 meters (over 2 yards) long and wide; for small animals, proportionately smaller. From the bottom of the pit a second excavation is made, likewise 2 meters long and 0.75 meter deep but only 1 meter in width, so that the lower, narrower pit

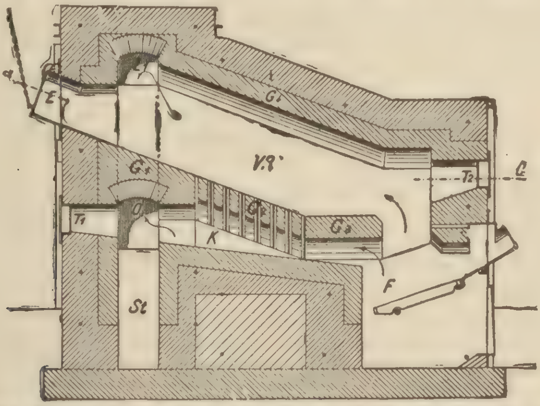

Fig. 268. Crematory furnace for small and medium-sized slaughterhouses, etc. *E*, Entrance; *VR*, crematory space; G_2, perforated arch; G_3, horizontal continuation of the same; *F*, main fire. Most of the flames strike over the waste materials lying in the crematory space *VR*.

has a side or rim each half a meter (20 inches) in width formed by the bottom of the upper ditch. The bottom of the lower pit is covered with a layer of straw 25 centimeters (10 inches) deep, soaked in tar. The lower pit is filled to its rim with coarse wood arranged lengthwise and crosswise in alternate layers, leaving a free space of half a meter in width at each narrow side (ends) to facilitate a better draft and for lighting the straw, birch bark or other easily combustible materials. The woodpile is covered with a thick layer of straw. Two iron bearers or rails about 2 meters (yards) in length are placed crosswise across the lower pit so that they will bear the carcass. Between these bearers several boards of similar length are placed to serve as further support for the carcass. Upon this the carcass, with its belly cut open, is placed. The carcass is then completely surrounded with a layer of straw, 1 foot in thickness, pieces of board, twigs, tree roots, large boulders and the like, and finally the whole is carefully covered with clods of sod or peat as large as possible in size, whereupon the pile is lighted at one of the narrow sides. If the flame threatens to break through, the spot should

be covered at once with another clod of peat or sod. The air required for the combustion should enter at one of the narrow sides and blow the fire with great force, then finally escape at the opposite side and rise. After 5 to 12 hours the glowing ashes will contain only a few charred remains of the carcass. For the cremation of smaller carcasses 3 to 4.5 hundredweight of wood besides several kilograms (1 kilogram= 2.5 pounds) of tar are used; for larger carcasses 6.5 to 7 hundredweight of wood, or 1 to 2 hundredweight of wood and 4 to 6 hundredweight of briquettes. In districts where the ground-water level is high or where the ground is rocky this method of procedure can not be followed. It can of course be done only in the country where permanent arrangements for rendering infection harmless are impossible. On the other hand, establishments that meet the requirements of the fire regulations are necessary in cities and slaughter yards.

The utilization of steam boiler arrangements has not proved satisfactory for the cremation of all manner of animal refuse (because of trouble with soot and odor, soiling the grate, corrosion on the sides of the boiler) and has been declared inadmissible for sanitary police consideration.

The most satisfactory method today for destroying animal substances is the use of crematory furnaces (incinerators) for animal carcasses. They are suited to small slaughtering establishments where the quantity of condemned material is too small to be utilized to advantage (Fischer). Fig. 268 shows the construction of such a crematory furnace. The large combustion furnaces that can hold entire carcasses have a wide door that fits flat against the crown G instead of the sloping receiving compartment.

A nonportable crematory furnace is of limited value for farm conditions. Attempts have been made to overcome this disadvantage by the construction of a portable crematory apparatus—a crematory wagon for carcasses. This apparatus can be brought to the object that is to be consumed, thus avoiding entirely the danger of spreading the infectious substance by transportation. The apparatus consists of a horizontal cylinder 2.5 meters long and 1.25 meters in diameter, which rests upon a four-wheeled frame. The fire-box is at the rear end under the cylinder and an air-tight door is at the front end of the cylinder. Through this the carcass is introduced. To facilitate the introduction the cylinder is provided with a track on the inside that extends with a sloping level to the floor. A triaxial truck runs on the track, and the carcass is placed upon this and pulled into the combustion compartment by means of a windlass. The front part of the cylinder is provided with a chimney several meters in height. The burning of the carcass is done over a wood fire. To reduce a horse carcass to ashes about 200 kilograms (440 pounds) of wood are used. The combustion requires five to six hours. There is practically no annoyance from odors (Lange and Ohlandt).

c. Utilization of the Carcass

The simplest and oldest but also the poorest utilization of the carcass consisted in removing the hide or skin, collecting hair (horse hair), wool, bristles, feathers, hoofs, horns and bones (for wood turners, glue and fertilizer factories), cutting up the muscolature into long, narrow strips and drying it in the air for use as dog feed or as so-called glue leather in the glue factories. This method of procedure produces unpleasant odors, entices rats in great numbers, and is decidedly insanitary and impracticable with carcasses of animals that have suffered from diseases that can be transmitted to man.

This method has been abandoned in general, and efforts are being made even in small country knackers' yards to substitute newer methods.

Furthermore in knackers' yards that are not modern the disease carcasses are sometimes boiled in open kettles, with and also without sulphuric acid, until the soft parts fall to pieces, thus obtaining fat and a slime which is used dried as fertilizer powder. The larger carcasses must first be disjointed, which is not without danger for the person engaged in that work if the animal died of anthrax, glanders, etc., and which also favors the spread of infectious diseases. This work produces disagreeable odors that greatly annoy the neighborhood. The use of large quantities of sulphuric acid involves great danger for the persons engaged in the work. Moreover the products obtained are of inferior quality, and those containing nitrogen can be used practically only as fertilizer. This method of utilizing the carcass has therefore been abandoned more and more.

Francke recommended the treatment of condemned meat with 3 per cent caustic soda solution. After 24 hours' action the material is boiled until the soft parts fall entirely apart (about two or three hours). The fat should not be saponified thereby. Fat, glue, liquor and alkali albuminate are obtained. The method should be cheap.

Finally the utilization of the carcass by means of dry distillation can not be designated as an unobjectionable method. The odors are generally obnoxious and the economic importance of the procedure is very slight. This process is rarely ever used now.

From a sanitary and economic point of view the modern arrangements for such utilization must comply with the following rules:

1. The accumulating raw material to be used should be thoroughly sterilized and the recovery of unobjectionable products must always be guaranteed by rigid separation of the "clean and unclean side."

2. All danger and annoyance to workers and the neighborhood must be avoided.

3. As complete and economical a utilization as possible of the raw material in the form of feeds and technical preparations (e.g., fat) of good quality must be provided.

The most modern and, up to the present time, the best method of utilizing the carcasses is *steaming* under several atmospheres pressure in special apparatus. In a certain sense this is justly called *thermic utilization.* It makes possible a complete destruction of the disease-producing bacteria (sterilization) and the manufacture of products that are greatly desired in the technical arts and farming. On the other hand the manufacturing plants referred to do not always fully meet the demands made in the interest of adjacent inhabitants and of the workers, namely, odorlessness. But certain individual cases have proved without a doubt that even such establishments can be operated even in the midst of settlements without special concern.

In the technical utilization of the carcass, in so far as veterinary po-

lice regulations do not interfere, the skin is first removed, then the entire remainder of the body is worked over into fats and nitrogenous substances. The fat that is obtained serves for technical purposes, especially in the soap industry. The body meal, rich in nitrogen, is a useful concentrated feed.

By means of the thermic handling of carcasses the meat and bones are rendered and dehydrated by the steaming so that the residue can easily be dried into a meal that will keep. The broth resulting from the steaming contains glue which results from the action of the superheated steam on the glue-yielding substances (connective tissue, ligaments, tendons, cartilage, bones) of the body. The broth was formerly evaporated into a glue-gelatin which was then used in the building trade for stucco work (plaster of Paris). It can not be used as glue since it has lost the adhesive quality through the prolonged action of high temperature. Since the outbreak of the war the glue-gelatin has served for food purposes: Since this time the separate utilization of the broth as glue-gelatin has been abandoned more and more, and the broth is now thickened with the remaining mass of meat and bones into animal meal that contains the glue. The broth as well as the meat extract contains in addition to the glue a quantity of dissolved substances such as albumose, peptones, meat bases, salts, etc.

The number of *apparatuses* that have been constructed for the thermic handling and utilization of carcasses is already quite large. A discussion of all systems would be beyond the scope of this book. For large establishments for the utilization of carcasses special consideration should be given to the continuously working apparatus. The Podewil system is illustrated in Fig. 269. With this method the carcass material is put into the apparatus through the manhole aperture M, whereupon the manhole is sealed gas-tight. In the meantime the fluid in the hot-water montejus is heated by boiler steam. A part of the heated fluid is forced over into the apparatus through the pipe Z, and the heating jacket is heated with the boiler steam until a pressure of 3 atmospheres exists in the inner cylinder. This pressure is maintained for about four hours and the apparatus is occasionally set rotating. All disease germs are positively destroyed by the action of the hot fluid and the carcass is cooked to a mash. The amount of fluid that remains in the hot-water montejus is then forced entirely into the apparatus so that the inner cylinder fills to the top. The fat floating on top then flows through the opened stopcock F into the pipe F, passes the cooler K and gas separator G, and is finally drained through the drain pipe R into a grease barrel in a clean, cooled condition ready for the market. After this the same amount of fluid as was taken out of the montejus is again conveyed into it, to be used at the next filling in a like manner. The carcass material that remains is dried in about seven hours by the action of the boiler steam that has been let into the heating jacket and by the

sucking off of the steam from the inner cylinder through rotation of the entire apparatus, and at the same time is changed into a finely ground, marketable, dry product (meat and bone meal) by the roller W, which lies loose in the rotating apparatus. After opening the manhole M, and after about ten minutes' rotation, the apparatus empties itself automatically into the truck that is placed below. The carcass vapors that are formed during drying in the inner cylinder are sucked off by the air pump through the bent pipe and are mixed with water in a condenser and then condensed. This condensed water is the only waste water that results. It is quite harmless and clear. The small quantities of gases that do not condense are led under the fire grating of the steam boiler

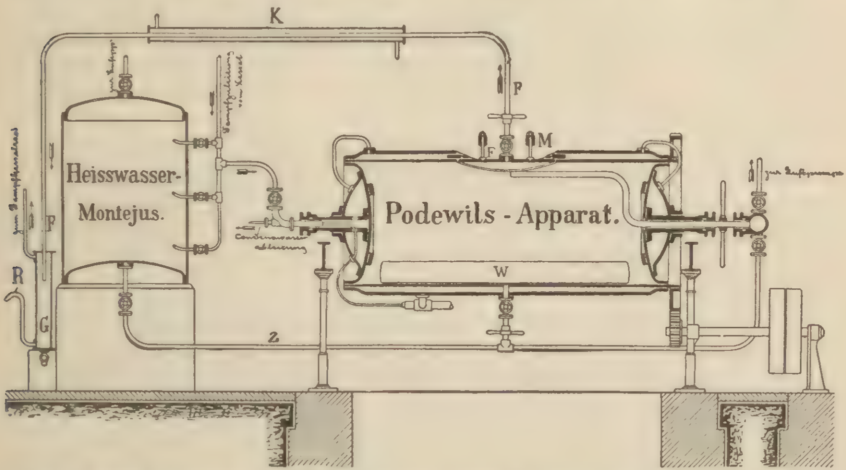

Fig. 269. Podewils apparatus. *Z*, Pipe connection between Podewils apparatus and the hot water montejus; *F*, grease drain pipe; *G*, gas separator; *K*, grease cooler; *M*, manhole closure of the Podewils apparatus; *R*, pipe from draining clean, cooled grease; *W*, unattached grinding roller in Podewils apparatus. The accessory machinery (steam boiler, motor and air pump with condenser) is not shown in this illustration.

and are burned there. The pure heating water that is condensed from the boiler steam in the heating jacket of the apparatus is given back into the steam boiler. The entire process lasts from ten to twelve hours.

For the purpose of putting in whole carcasses the Podewil apparatus can also be provided with a side opening and be so arranged that it can be brought from the horizontal into a vertical position.

The Podewil method permits the utilization of diseased carcasses without their being disjointed, therefore does not endanger the workers. It works without producing disagreeable odors, and by utilizing diseased carcasses will even yield harmless, unobjectionable, valuable animal meal which is in great demand as feed. Nevertheless the fat is subjected, during the entire cooking process, to the carcass vapors that contain ammonia and is not taken from them until at the end of the boiling. The yield from a mixed utilization of carcasses and condemnations ob-

tained during meat inspection amounts to about 10 per cent of fat and about 21 per cent of meat and bone meal.

With the Sommermeyer apparatus that works continuously the entire charge need not be worked up and the steam pressure need not be released before new raw material is added. Much time and expense are thus saved and the efficiency of the apparatus is increased.

Fig. 270 illustrates the Sommermeyer apparatus, with all attachments schematically represented. *A* is the filling container for the extractor *B*, inside of which the revolving screen *C* is built in. *D* is the fat separator and *E* the receiver and evaporator. *F* is an automatic loading arrangement for the shaking sieve *G*, from which comminuted and extracted raw material freed of fluid is aided into the drying apparatus *H*. Finally *J* is an elevator which transports the finished dry product to the storeroom, where it is freed by a sifting machine of hairs, etc., that are mixed in, and is ground to a uniform meal.

The manner in which the entire apparatus works is as follows: First the shut-off *a* between the filling container *A* and the extractor *B* is closed, and steam of three to four atmospheres pressure is conducted into the extractor *B*. Then with the aid of the levers *c* and *d* the upper lid *b* of the filling container *A* is opened and the container *A* is filled with carcass material. *b* is again closed and with the help of the valve *e* an equalization of pressure is established between the extractor *B* and the container *A*. As soon as the same pressure exists in both vessels the lower trapdoor or shut-off on container *A* opens, and the carcass material automatically falls into the sieve cylinder *C* of the extractor *B*. The sieve cylinder *C* is set in motion and the extraction begins. Then trapdoor *a* is closed again and more carcass material is put into the container *A* in the manner just described. Through the action of the superheated steam and the automatic movement of the rotating sieve cylinder the meat and bone masses in the extractor *B* are reduced to small pieces at the same time that the separation of the fat and cooking broth occurs, even to such an extent that they fall through the holes of the sieve cylinder into the space between the latter and the extractor wall. Here they are seized by the stirring arms which are adjusted on the outer edge of the sieve cylinder, and are carried to the overflow pipe that leads to the fat separator *D* and that can be closed by valve *f*. Here the various parts of the mixture separate according to their specific weight. The small pieces of carcass material deposit themselves on the bottom of the vessel; the cooking broth is over this and at the highest point the fat separates. This becomes visible in the specimen glasses *g* and *h* and is drawn off at a given time by the valve attached there. An appropriate arrangement takes the completely grease-free broth to the receivers and evaporator *E*, opposite where thickening or concentration takes place. The carcass material that has been reduced to small pieces after it has been sufficiently extracted is conducted through a closed pipe towards

the shaking sieve *G* through the automatic loading device which provides for the separation of the fluid that is still adhering, and conveys the dry material in desired quantities through the overflow *l* to the dry apparatus *H*. The securing of glue-free and glue-containing animal meal can be accomplished at will. The completed dry product falls into the elevator shaft and is transported by the elevator *J* to the storage room.

The products have been improved in quality compared with former results. The yields have improved since, as a result of the shorter action of the superheated steam upon the raw material it has converted decidedly less quantities of the glue-producing substances into glue. That

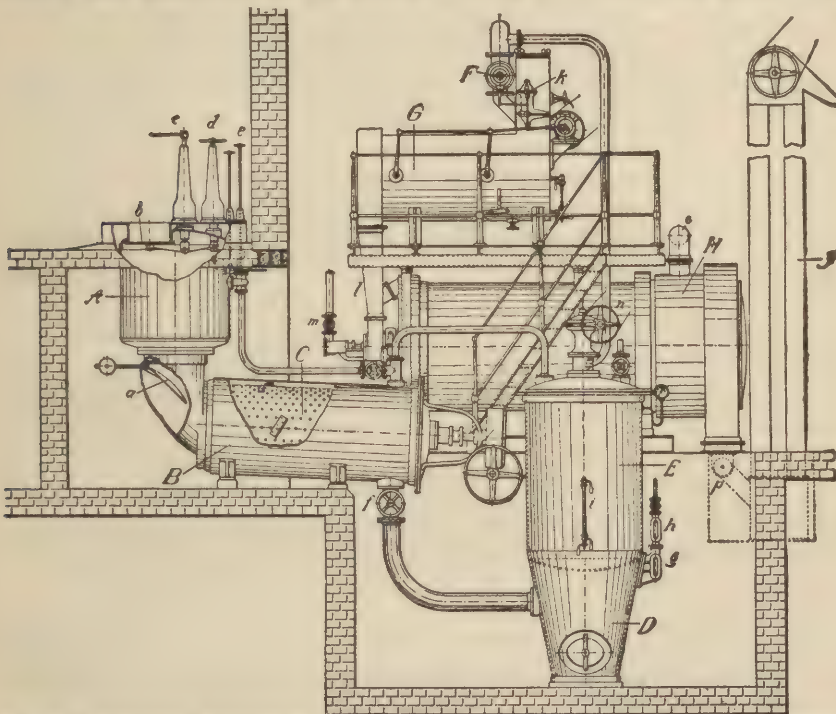

Fig. 270. Continuously operating carcass utilization apparatus (rendering plant). Patent of Sommermeyer (Rud. A. Hartmann, Berlin).

means that more animal body meal is obtained. The fat yield is also better.

For knackers' yards the apparatus is chosen large enough to allow an average of 1,000 kilograms (1 ton) to be worked through in an hour. The next smaller size is arranged for 500 kilograms per hour.

With the help of the new Sommermeyer apparatus blood and mucus can be utilized without any further additional apparatus. This new apparatus, which depends on an entirely different principle from those previously known, makes possible the technical utilization of animal carcasses and slaughterhouse refuse by entirely new methods.

With the apparatus that works continuously the carcasses of large animals must unfortunately be cut up before being put into the apparatus, which is not necessary with apparatus by the same firm that works only half continuously. It is of course desirable for sanitary reasons to utilize the whole bodies of diseased animals.

With the Venuleth and Ellenberger method two boilers arranged one above the other, the disinfector and the drying apparatus, for boiling and drying. Both are securely walled in. The disinfector incloses a sieve cylinder that runs on wheels and can be pulled out. The fluid that drips through the sieve cylinder during sterilization is at once conducted to the receiver where it is separated into fat and glue broth. After the fat has been drawn off the glue broth is forced into the evaporator and there thickened into a gelatine which is converted into glue fertilizer with peat and potash. After the cooking, which has lasted three and one-half to four hours, and which was done under four to five excess atmospheric pressure, and after the material has been drawn off into the drying apparatus, the disinfector can be refilled. In addition to the apparatus with the separating system, Venuleth and Ellenberger also produce combined apparatuses which resemble the Podewil apparatus. Combined arrangements are also manufactured by other firms.

Portable apparatus has the disadvantage that a definite separation of the clean and the unclean can not be carried out and the finished products can not be protected from reinfection by carcass material that has not yet been utilized.

Finally, certain *chemical methods* work with special agents that dissolve fats (benzine, carbon disulphid, carbon tetrachlorid). The fat yield is larger and the meat meal not so rich in fat, but it keeps better. The disadvantages of this procedure are the danger of fire and the consideration that the bones are left in their former hard condition.

According to Westmattelmann's calculations, the available carcasses and parts in the province of Westphalia are sufficient for a production of 44,090 hundredweight, and in Prussia about 140,000 hundredweight, of animal body meal.

A *plant for the utilization of animal carcasses,* etc., should include boiler rooms, machine rooms, autopsy rooms (with the necessary instruments, which should be kept in order), mill rooms, storerooms and similar rooms, and above all a slaughtering room and the actual utilization section.

The slaughtering room should be used for skinning and performing autopsies on the animal carcasses as well as for killing animals brought there for that purpose. Since bad odors are unavoidable in the work with partly decomposed carcasses, the slaughtering room should be high and be provided with an efficacious ventilation system that connects with a high chimney. The slaughtering room should be shut off from the actual manufacturing place. The only permissible apertures in the par-

tition wall are those that are measured so as to receive the filling pipes that lead into the apparatus in which the material is worked up. Matters are facilitated if the slaughtering room is on a slightly higher level than the apparatus room.

Ample provision must be made for the water supply and for drainage. Infection of the finished products must be eliminated. The animal waste should if practicable be worked up also; otherwise it should be disinfected.

The *transport wagons* should be so arranged (lined with zinc or sheet iron) that they are absolutely tight and that liquid excreta can not drip down. They should be large enough to receive a whole carcass of a large animal. The wagons must be closed on top so that neither bad odors can escape nor insects get at the carcasses nor parts of the carcasses visible. If the wagons are used for the removal of remains from slaughtering yards they must be closed so that no parts can be stolen on the way. Furthermore the transport wagons must be provided with lifting or hoisting arrangements.

Under the German regulations, in the transportation of carcasses of animals that died from anthrax, blackleg or bovine hemorrhagic septicemia, the natural body orifices of the carcass must be sealed as well as possible by inserting tow, cloths or the like to prevent the escape of blood. The carcasses or parts must also be covered so securely that no flies can get at them. If possible only such wagons or containers should be used for the removal as are impervious to blood and animal excrement.

d. Dealing in Dead Animals (Knacker)

By a knacker is understood one whose business it is to remove carcasses that are no longer suited to human needs.

As early as the middle ages the knacker (in Germany) possessed legally established privileges, which were often entered in the statute books, as recompense because the business and its representatives were looked upon as "dishonest." These so-called ban rights were repeatedly confirmed in Prussia and also under Frederick the Great by the "Publikandum of April 29, 1772," which assigned certain districts to the knackers within which they were granted all animals (sheep excepted) excepting those that died from a disease and that were found unclean when slaughtered. In other words, owners were forbidden to utilize their own dead animals. These ban rights were nearly all dissolved later, but are doubtless still valid in some knackers' yards. In place of these privileges much more appropriate arrangements have been made, as, for instance, the erection of establishments by individual communities or entire districts for the thermic destruction of carcasses.

The oldest and poorest method of flaying or skinning consisted in simply allowing carcasses to lie at a place designated for this purpose and decompose or be attacked by carrion-eating animals, after the hide, the most valuable part, had been removed. This manner of removal of carcasses was, for example, still practiced in France (knacker's yard of Montfaucon in Paris) as late as the middle of the last century (Schieferdecker). Even now it often occurs in the country that small animals that have died or were born dead, with or without utilization of the hide, are cast upon the manure pile or into the urine pit, into the garden or on the field, into pools, brooks or rivers, and disposed of in this improper manner.

In comparison with this method, which favors the spreading of diseases, burying may be looked upon as a measure of considerable hygienic progress. But even here, as mentioned on page 402, serious dangers are not excluded in the resistance of certain infectious germs (anthrax spores).

In early times the knackers sought to make the most of carcasses and attempted to utilize hides, hair, hoofs, horns, fat, meat and bones. The preparation of these raw animal materials in knackers' yards involved many disadvantages. Obnoxious odors were formed by the extraction of the fats, the drying of the meat of the skins, etc., by the decomposition of remains, especially the intestines thrown on the manure heap or into ditches, by the burning of animal excreta in unsuitable stoves, and the opening and utilization of old, decomposed carcasses. Again, many grave dangers are involved with such utilization of carcasses, during which procedure many of the disease bacteria that are present are not destroyed. Aside from the fact that the knackers themselves may become infected during dissection, the so-called raw materials that are utilized partly as food for dogs, hogs, chickens and fish, partly as fertilizer, etc., are often carriers of infection.

A far better hygienic utilization is the boiling of the carcass to a mash with or without the addition of sulphuric acid. The fat that separates can be skimmed off the top and utilized technically, and the dried residue can be marketed as fertilizer. But neither can this procedure be called unobjectionable.

The only certain and reliable utilization is offered by an apparatus in which all, even the large carcasses, can be worked over in one piece with hair and hide and be completely sterilized, as is the case with the thermic apparatus for utilization, e. g., Podewil's (already described).

The German law concerning the removal of animal carcasses requires the harmless removal of carcasses or their parts of all horses that have died or been killed, of donkeys, mules, asses, cattle, hogs, sheep and goats, in so far as their utilization is not allowed. The harmless removal must take place through burial if it can not be done by a high degree of heat (boiling or steaming until the soft parts fall to pieces, dry distillation, burning) or by chemical means until the soft parts dissolve.

The regulations of the German federal council for this procedure, issued March 28, 1912, forbid the use of the carcasses or parts of carcasses for human food, but permit, with the preceding restrictions, and as long as veterinary police regulations do not oppose, the utilization of the skin, fat (after boiling or rendering), bones, horns, hoofs, hair, wool, bristles, and feathers after boiling or drying. The meat may be used as food for animals (*a*) on the owner's farm; (*b*) outside of his own farm with the consent of the police authorities and after thorough cooking and coloring of the meat.

By the order of the Ministry of the Interior of Saxony, concerning the removal of animal carcasses, meat condemned in the meat inspection, etc., June 6, 1912, the preceding imperial law is extended to all dogs, cats and poultry that died, were killed or were born dead. Slaughtering an animal by bleeding it to death is not looked upon as killing the animal. The burial (generally excluding dogs, cats and poultry) may take place only on suitable burial places previously agreed to by the district veterinarian and district physician. The medical authorities may prescribe the delivery to special plants having thermic and chemical arrangements for

the harmless removal of carcasses, or to knacker's yards, in place of burial.

The death or killing of horses, donkeys, mules and asses over three months old, also of cattle, sheep, goats or hogs, must be reported within 24 hours to the local authorities. In independent estates of the "Amtshauptmannshaft" the removal is done at the expense of the owner.

The proclamation of the imperial chancellor concerning the utilization of carcasses and slaughter refuse, June 29, 1916, which decrees that the carcasses and parts of carcasses in larger knacker's yards and slaughter-houses must be utilized for feeds and fats, is of national economic importance.

Supplement—Reminders for Horse Attendants

The following page of reminders is intended for the coachman or horse attendant. It is advisable to give him these notices copied legibly or to fasten it to the stable door or at some other suitable place.

1. Feed your horse punctually three times a day; evenings abundantly, mornings sparingly. When working at night practice the reverse. If going out, feed at least two hours before.

2. Let your horses eat in peace; groom them afterward.

3. No grain feed without plenty of chopped straw.

4. Always corn, oats, when necessary hulled grain (for run-down horses).

5. First grain, then coarse feed.

6. Whoever loves his horse will water him when and where he can, and not only three times a day before and after each feeding. Above all do not forget to offer water before each harnessing. Take care that the water is not too cold in the winter.

7. Always keep your horse clean. Well groomed is half fed. The coat (hair) will show the condition of the horse and the diligence of the attendant. If possible groom out of doors.

8. Clean the hoofs each time before and after work. Pay attention to the shoeing, bent-in nails, frog rot, etc. If a horse interferes apply an interfering pad or a straw ring over the fetlock joint.

9. Always report every illness at once (lack of appetite, injuries, scraped places, etc.).

10. Place wisps of straw on the back under the girth.

11. During cold weather do not put on the horse a bridle in frozen condition. Hang it up in the stable or first hold the bit in warm water.

12. Always harness up conscientiously. See that the harness fits.

13. On smooth and slippery roads screw in the calks. Surefootedness makes the work easier. Look after the shoeing frequently. The ab-

sence of one calk may cause lameness. After unharnessing take out the sharp calks.

14. If you drive along bad roads at night, let your horses walk quietly and hold them well in check. At other times do not let the reins hang and never sleep while driving.

15. Spare your horses; relieve them of their work whenever you can; give them rests to blow; walk often beside the horses, always uphill and downhill; it will do you and your horses good.

16. At each rest look at harness and shoes. Pressure results easily but it heals slowly. Water.

17. After arriving home attend first the horses and then the man. Rub down. Wet or overheated horses should also be blanketed. Water sweating horses after half an hour and place a little hay on the water.

18. Provide dry, warm, soft bedding.

19. Give the horses their night rest. The stable watch should place the lantern in a pail to prevent blinding.

20. When you are angry, do not vent your anger on your horses, but always treat them gently and kindly. Talk much to them, and thus you will awaken their affection and confidence.

INDEX